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ROYAL COMMISSION ON SEWAGE DISPOSAL.

FIFTH REPORT

OF

THE COMMISSIONERS

APPOINTED TO INQUIRE AND REPORT WHAT METHODS OF

Treating and Disposing of Sewage

(INCLUDING ANY LIQUID FROM ANY FACTORY OR MANUFACTURING PROCESS)

MAY PROPERLY BE ADOPTED.

Methods of Treating and Disposing of Sewage.

APPENDIX II.

SUMMARY OF EVIDENCE ON CERTAIN QUESTIONS.

Presented to both Houses of Parliament by Command of His Majesty.

LONDON:
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BY WYMAN & SONS, LIMITED, 109, FETTER LANE, E.C.

And to be purchased, either directly or through any Bookseller, from
WYMAN AND SONS, LIMITED, 109, FETTER LANE, FLEET STREET, E.C.; and
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1908.

[Cd. 4280.] *Price* 1s. 10d.

Presented by

Purchased

October 1908

ROYAL COMMISSION ON SEWAGE DISPOSAL.

SUMMARY OF EVIDENCE ON CERTAIN QUESTIONS.

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(1.) DO TRADE EFFLUENTS INTERFERE WITH THE PROCESS OF PURIFICATION BY REASON OF THEIR QUALITY, VARIATIONS IN COMPOSITION, FLUCTUATIONS IN VOLUME OR OTHERWISE. SEWAGE.

Interim Report: Vol. II. (*Cd.* 686) 1902.

336
248–52 *Dr. Maclean Wilson*: With the one exception that acid effluents might interfere with any biological treatment, it would not be difficult to deal with combined sewage, if some form of chemical treatment was adopted followed by filtration, because the chemicals could be adapted to deal with anything objectionable in the mixed sewage. Acid liquors from dye works and a particular acid iron waste liquor (Leeds) worst kinds of refuse for biological treatment. Wool suds also difficult to treat on account of grease which clogs filters and land.

2418–20
2438–9 *Dr. Adeney*: Aërobic fermentation will not take place in distinctly acid sewage; but discharge of considerable quantity of free acid into sewers might be allowed, because alkalinity of sewage would take up a large quantity. Alkalinity beyond a certain limit is very inimical to bacterial fermentation. There can be no latitude to manufacturers in case of alkalis.

Iron compounds, unless too acid, not troublesome, assist in clarification. Large quantities of soap are a serious matter.

2547 *Prof. H. Marshall Ward*: Acidity and alkalinity affect the life of bacteria.

4144 *Dr. Rideal*: Soap-suds and greasy matters give rise to serious mechanical trouble.

6627 *Mr. R. A. Tatton*: Yes, through irregularity in flow and in quality. Refers in particular to waste from breweries, distilleries, woollen works, tanneries, fellmongers, dye works, chemical, and ironworks.

Third Report: Vol. II. (*Cd.* 1487). 1903.

12237–8 *Mr. T. C. Beeley* (*Hyde*): Yes, owing to the character of the refuse and the intermittency of the flow.

12284–9 *Mr. S. S. Platt* (*Rochdale*): Evidence to same effect as that of Mr. Beeley. Refers in particular to wool scouring refuse which is very difficult to treat and is sent to disposal works very irregularly.

15469–7 *Mr. J. Corbett* (*Salford*): No difficulty at Salford. Works deal with dye refuse and refuse from print works, iron works and breweries, and the refuse is received in irregular quantities.

(1.) Do Trade Effluents Interfere with the Process of Purification by Reason of their Quality, Variations in Composition, Fluctuation in Volume, or Otherwise (*continued*).

Fifth Report: Appendix I.

20710 *Messrs. Raymond Ross & Pickles* (*Burnley*): Considerable difficulty at one time through excessive discharge during short periods of very concentrated dye effluent. No difficulty now effluent is run through sedimentation tanks and thence into sewers by continuous flow.

21077 *Mr. Bolton* (*Heywood*): No material interference when trade effluents are delivered in a regular stream (this applies to brewery, dye, tannery, and fellmongers' waste as at Heywood). When large volumes are turned in at irregular intervals, chemical treatment is disorganised.

21409
21411 *Mr. Kershaw* (*Rotherham*): At Rotherham trouble with waste from works where gas liquor is treated for recovery of ammonia. Refuse is heavily charged with sulphides and sulphocyanides, etc. It has high oxygen absorbent properties and interferes seriously with results owing to nature of effluent rather than on account of volume.

21584 *Mr. Campbell* (*Huddersfield*): Trade refuse not so amenable to treatment as domestic sewage. Difficulties also arise from variations in composition and in volume (due to irregular discharge), increased amount of solids, etc.

21962 *Mr. Harrison* (*Leeds*): If trade effluents are free from suspended solids, are admitted at a uniform rate over the twenty-four hours, and are not great in volume compared to the domestic sewage, no difficulty is experienced. If these conditions are not fulfilled, dye liquors and iron liquors sometimes have deleterious effects.

22302
22497–8 *Mr. Valentine* (*Oldham*): Principal difficulty at Oldham is with waste from mill lodges or reservoirs. This is over-septicised, stagnant, and concentrated sewage, and has adverse effect upon the filters for several days after it is sent down to the works.

22585 *Dr. Wilkinson* (*Oldham*): Effluent from mill reservoirs renders the sewage very concentrated and foul, and on one occasion the admission of a large quantity of beer into the sewers had a very marked effect on the filters.

22729 *Mr. Fowler* (*Manchester*): Yes: certain trade effluents interfere with process of purification, *e.g.*, iron pickle, by increasing deposit in septic tank and amount of insoluble matter going on to beds; naphtha washings, ammonia recovery liquor, and some dye-waste, by increasing the oxygen absorbing power of the sewage. Generally, the presence of trade effluents increases the periods required for bacterial activity to mature in both septic tanks and filters.

(1.) Do Trade Effluents Interfere with the Process of Purification by Reason of their Quality, Variations in Composition, Fluctuations in Volume, or Otherwise (*continued*).

185 *Mr. Carter Bell* (*Salford*): Not found any difficulty: sometimes tarry matter affects oxygen test.

596 *Mr. Haworth* (*Sheffield*): Difficulties arise for various reasons, in some cases, on account of the character of the particular waste (*e.g.*, brewery waste, iron pickle, ammonium sulphate waste), and in some cases, on account of irregular flow, large volume, etc.

654–5 Very desirable and necessary that trade effluents should be distributed equally over the twenty-four hours.

432 *Dr. Reid*: Has had experience only of acid waste from galvanising works, brewery waste, and waste from
. 573) works for recovery of ammonia from gas liquor. As regards first-named, difficulties arise where the volume is in large proportion to the domestic sewage, and special precautions are necessary, including treatment by the manufacturer of the spent acid portion, and uniform discharge of the wash water.

615–7 Acid sewage, such as at Wolverhampton, requires preliminary treatment by chemicals before filtration.

In the case of brewery waste, when present in considerable quantity, more efficient means of treatment is necessary. Ammoniacal liquor waste, when present in large quantity, renders the sewage impracticable to treat by any known process.

932 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): Much difficulty has been caused by sudden discharges of trade effluents, such as waste gas liquor and waste metal pickling liquor. The low alkalinity of the sewage caused by trade effluents accompanied by the presence of ferrous salts also prevents septic action in some cases.

003 *Messrs. Willcox and Raikes*: Trade effluents at Hanley (consisting of mine water and waste water from potteries and paper mills) do not interfere with purification of sewage, but the clay in the pottery waste materially increases the quantity of sludge and consequently the expense of treatment.

SEWAGE.

(2) HOW SHOULD "STRENGTH" OF SEWAGE AS AFFECTING PURIFICATION BE BEST EXPRESSED OR MEASURED.

Fifth Report : Appendix I.

20716 *Messrs. Raymond Ross & Pickles (Burnley)* : By a full analysis, including free and organic nitrogen, suspended matter (organic and inorganic), dissolved solids (organic and inorganic), cellulose and grease : 3 min. oxygen test for trade effluents : germicides.

20820 Any one figure might give a fairly approximate idea of strength if the local circumstances were known. The quantity of oxygen required to oxidize sewage would be a sufficient measure of strength in that case (21030–3.)

21083 *Mr. Bolton (Heywood)* : Best by the albuminoid nitrogen and oxygen absorbed figures.

21590 *Mr. Campbell (Huddersfield)* : By amount of nitrogenous organic matter, and of oxidisable organic matter as measured by four hours' oxygen absorption. Chlorine should also be estimated to show that sewage and effluent are identical.

22397 *Mr. Valentine (Oldham)* : By the chlorine content, and the amount of oxygen absorbed in four hours from permanganate.

22591 *Dr. Wilkinson (Oldham)* : Probably the number of grains of oxygen absorbed by the permanganate test is as good as any, except where there is an excess of acid or chemical ingredient

22735 *Mr. Fowler (Manchester)* : Best measured by the number of gallons per head of the population arriving at the works daily, allowance being made for character and volume of any trade wastes. The chlorine number, when not affected by trade effluents, is a good index : the ammonia figures give a better indication of presence of real sewage than the permanganate test.

22886–901 The greater the number of gallons per head the weaker the sewage.

23191 *Mr. Carter Bell (Salford)* : By stating the percentage of purification derived from the oxygen test (*i.e.* permanganate : four hours' test : 23289–90).

23600 *Mr. Haworth (Sheffield)* : For practical purposes the determination of oxygen absorbed in four hours and albuminoid nitrogen indicate the strength fairly satisfactorily. Both tests to be taken together (23658).

(2.) How should "Strength" of Sewage as Affecting Purification be Best Expressed or Measured (*continued*). **SEWAGE.**

432 (p.573) *Dr. Reid*: By the albuminoid and oxygen absorbed figures

673 *Dr. Letts*: Difficult, if not impossible, to give a comprehensive answer. A sewage may be "strong" in several different ways in relation to purification, of which the chief are (1) suspended solids; (2) putrescible organic matter; (3) free or saline ammonia. Sewage may be very strong as regards one factor, yet weak as judged by another.

938 *Messrs. Watson & O'Shaughnessy (Birmingham)*: By comparing figures for albuminoid ammonia and for oxygen absorbed in four hours at 80° F. in the sewage and effluent, respectively.

578 *Dr. W. E. Adeney*: Gives results of certain experiments supporting the view held by him that the adoption of the aeration method of analysis is a necessity for the accurate determination of "strength" of a sewage or tank liquor. These results are confirmed by a large number of other experimental investigations.

009
48 *Messrs. Willcox & Raikes*: By the amount of suspended matter and the oxgyen absorbed figure. This is regarded as the most convenient test from a purely practical point of view.

STORM WATER SEWAGE

(3.) ARE THE AMOUNTS OF SUSPENDED SOLIDS IN SEWAGE INCREASED OR DIMINISHED IN TIMES OF STORM.

Fifth Report: Appendix I.

20720 *Messrs. Raymond Ross & Pickles*: First increased: afterwards diminishes rapidly. Figures for storm of four hours' duration between the hours of 1 a.m. and 5 a.m. :—

Average sample during	Suspended matter.
1st hour	24·8
2nd ,,	80·0
3rd ,,	25·6
4th ,,	5·6

See also 20821–6.

21087 *Mr. Bolton* (*Heywood*): Greatly increased in times of storm. Storm of four hours' duration gave following figures :—

First rushes	238	parts per 100,000
After 1 hour	110	,, ,,
,, 2 hours	69	,, ,,
,, 3 ,,	50	,, ,,
,, 4 ,,	38	,, ,,
,, 5 ,,	33	,, ,,
,, 6 ,,	28	,,
,, 7 ,,	18	,, ,,

21420 *Mr. Kershaw* (*Rotherham*): Very largely increased in storm times.

21594 *Mr. Campbell* (*Huddersfield*): Yes, and the amount varies according to condition and inclination of sewer.

21970 *Mr. Harrison* (*Leeds*): Suspended solids during short heavy rain-storms are usually very high. The amount varies directly with the hourly rate of rainfall. In the case of storms lasting over considerable periods, the storm water sewage contains practically on an average (22249–55) the same amount of suspended matter as ordinary sewage. The amount of organic impurity present, however, is much smaller.

22401 *Mr. Valentine* (*Oldham*): For some hours, the amount is greatly increased; then it decreases until the amount is appreciably less than in normal flows.

22595 *Dr. Wilkinson* (*Oldham*): At first the amount is increased very rapidly; but, after a short time, the amount decreases rapidly.

(3.) Are the Amounts of Suspended Solids in Sewage Increased or Diminished in Times of Storm (*continued*). STORM WATER SEWAGE.

22739 *Mr. Fowler* (*Manchester*): Certainly, during the earlier periods of a storm. After considerable period of rain, the total suspended matter is little more than the average, and consists largely of mineral matter. These statements are illustrated by analyses.

23195 *Mr. Carter Bell* (*Salford*): Increased at first; but, if rain is long continued, amount of suspended solids diminishes.

23505 *Mr. Wike* (*Sheffield*): Largely increased at first; but proportion diminishes if rainfall is prolonged.

23604 *Mr. Haworth* (*Sheffield*): Suspended solids during storm (rainfall ·11 inch):—

Time.	Parts per 100,000.		
	Total Solids in Suspension.	Mineral.	Organic and Volatile.
10.50 a.m. before rain	59·24	9·92	49·32
11.50 a.m.	60·24	5·04	55·20
12.50 p.m.	67·12	13·20	53·92
1.50 p.m.	170·07	76·62	93·45
2.50 p.m.	125·93	50·55	75·38
3.50 p.m.	133·46	63·03	70·43
4.50 p.m.	101·20	67·33	33·87
5.50 p.m.	100·60	47·06	53·54
6.50 p.m.	97·93	26·93	71·00
7.50 p.m.	41·73	15·33	26·40
8.50 p.m.	40·06	18·66	21·40
9.50 p.m.	26·26	15·06	11·20

The first determination was made before the effects of the rain were observed at the works, and the final one when the storm overflow nearest the works ceased to operate.

24432 (p. 574) *Dr. Reid*: Largely increased in populous towns, especially after dry weather. Not so much in the case of scantily populated places.

STORM WATER SEWAGE

(3.) Are the Amounts of Suspended Solids in Sewage Increased or Diminished in Times of Storm (continued).

24942 *Messrs. Watson & O'Shaughnessy (Birmingham)*: Yes: suspended solids have risen from thirty-eight parts to 380 parts per 100,000 within an hour, owing to sudden storm.

26013 *Messrs. Willcox & Raikes*: Yes: amount of suspended solids is increased by road detritus and accumulations washed out of sewers.

(4.) IN WHAT WAY OR WAYS SHOULD THE SEWAGE BE DEALT WITH IN STORM TIMES.

STORM WATER SEWAGE

Interim Report: Vol. II. (Cd. 686), 1902.

1866 2126-30 *Mr. D. Cameron (Exeter)*: Only first washings from streets and sewers need be treated. Suggests that storage should be provided at the works from which there would be an overflow. This overflow being independent of the rate of flow in the sewers would enable the first washings to be dealt with.

7531-51 *Mr. G. R. Strachan*: Separate filters for excess storm water essential. Would fully deal with all sewage and storm water up to 80 gallons per head of population. Would treat flow from 80 to 120 or 150 gallons per head (preferably 150) in storm water filters and allow anything above to overflow to stream.

Fifth Report: Appendix I.

20647-8 *Dr. Reid*: Thinks it reasonable to require local authorities to deal with flow up to six times the dry-weather flow, and considers that in some cases storage tanks should be provided to take the first flush from sewers.

20728 *Messrs. Raymond Ross & Pickles (Burnley)*: Up to three times the dry-weather flow should be treated on the contact beds after passing through the septic tanks. When flow is much above this, the most polluting portion of the sewage (the first part) should be run through the septic tanks, and the remainder through detritus tanks and on to storm beds.

With moderate amount of storm water, it has been found advantageous to hold it up on land areas, and then run it on to storm beds.

20827 If tank capacity is sufficient, no damage to contact beds by passing storm flow through.

21090 21250-66 *Mr. Bolton (Heywood)*: Method required by Local Government Board not the most satisfactory. Admission of three times dry-weather flow to tanks results in a very unsatisfactory tank effluent (incoming sewage enters almost at bottom of tank), and the effect of this effluent on the filters is almost ruinous. The storm filters dealing with the flow above this are found to choke rapidly.

Thinks a good plan would be to pass twice the dry weather flow through the ordinary tanks, and from two to six times through special settling tanks having a capacity equal to six hours' flow. A portion of the effluent from these tanks could be passed through percolating filters more rapidly than could an effluent from the ordinary dry-weather tanks when receiving three times dry-weather flow.

21293-42 The principal thing is to remove the suspended matter, and this could be done by an hour's stay in special settling tanks.

2142[illegible] *Mr. Kershaw (Rotherham)*: Risk of damage to ordinary plant by passing storm sewage through depends upon circumstances, *e.g.*, on the condition of the tanks, whether they are comparatively clean, or contain a large amount of sludge. In the former case, little or no harm to the filters would arise; but, in the latter case, choking of filters from the washed-out sludge from the tanks is probable.

Settlement alone, without some form of subsequent filtration, would not be likely to prove a satisfactory method of dealing with storm sewage. It would give very good results, though not thoroughly satisfactory (21511-2).

STORM WATER SEWAGE.

(4.) In what Way or Ways should the Sewage be dealt with in Storm Times (*continued*).

21597 *Mr. Campbell* (*Huddersfield*): Requirements of Local Government Board work satisfactorily, in majority of cases; but in some cases full treatment in ordinary plant of flow up to three times the dry-weather flow exposes the plant to damage. Where storm water is not very polluting, it would be sufficient to provide for dealing with any flow above ordinary dry-weather flow in sedimentation tanks and then on special storm beds.

21721-8 Not less than six times the dry-weather flow should be treated.

21972 *Mr. Harrison* (*Leeds*): Thinks that storm water sewage up to three times the dry weather flow should undergo efficient treatment. If nearly all solids are removed by preliminary treatment, then six volumes may be treated on the ordinary plant: if some solids are present, then three volumes can be treated on the ordinary plant, and the remainder by special storm filters, settlement, or precipitation. This applies only to continuous filters, and to comparatively weak sewages.

At Leeds it was found possible to treat satisfactorily the whole volume of storm sewage up to six times the dry weather flow, after chemical precipitation, on percolating filters at rates varying from 600 gallons to 1,200 gallons per square yard per day. Good results were obtained at these rates over a considerable period (22077–95). (*See also* 22181–4.)

22404 *Mr. Valentine* (*Oldham*): All the sewage coming down should be sent partly through the ordinary settling tanks, and partly—the greater portion—through special storm tanks of large capacity. The first portion of the flow should be treated fully in the ordinary dry-weather plant, and, if the storm continued, it would be sufficient to run the highly diluted and settled sewage continuously through special filters (not necessarily retained for that purpose alone). Advisable to have storm filters for use in emergency, but they should be kept in condition by being dosed occasionally with weak settled (or precipitated) sewage in dry weather.

22493 Has used ordinary beds in time of storm (after sedimentation) and found no ill effects either as regards efficiency or capacity.

22597 *Dr. Wilkinson* (*Oldham*): With sufficient tank room, the first flow can be dealt with on the ordinary plant. After the first flush, sedimentation in a quiescent tank gives a very clear effluent. But settlement alone is not sufficient for the first rush of storm water.

22741 *Mr. Fowler* (*Manchester*): At least six times the dry-weather flow (*i.e.*, the *strict* dry-weather flow as based on the water supply; but the six times dilution should be calculated from time of greatest daily dry-weather flow), and, if possible, more, should be treated in some way. Tho whole volume should pass through the tanks, and the first flush should be fully treated as far as possible on the filters. After the first flush, some portion of the storm water might pass directly to the stream, provided that the suspended matter was not excessive.

The increased burden put upon beds in storm times does not materially harm them, if they are designed to cope with an average volume in dry and wet weather.

Settlement alone is not sufficient for all the storm water coming down, and the addition of chemicals is of little, if any, use.

22961 Very quick passage through tanks will remove from storm water a very large proportion of the suspended solids.

23077-9 Not possible to deal satisfactorily with storm water sewage on streaming filters alone. Previous settlement necessary. A storm filter to be effective must be fine, and if fine a large part of suspended matter must be previously settled.

5663-4 (Interim Report: Vol. II., 1902) Suggests that there would be advantage in mixing the effluents, *i.e.*, the partially treated effluent with the fully treated effluent.

(4.) In what Way or Ways should the Sewage be dealt with in Storm Times (*continued*). STORM WATER SEWAGE

23198 *Mr. Carter Bell* (*Salford*): In the case of Salford, best provision for storm flow would be large reserve tanks to hold (say) one day's storm flow, which might pass through the ordinary works during following days. Does not approve of special storm filters, as these become inefficient when used only intermittently. (No experience of storm water filters: 23261, 23293–4.) Cost of the reserve tanks suggested would be very high (23386–7).

23507 *Mr. Wike* (*Sheffield*): The amount to be treated should depend on the volume and character of the liquid. Ordinary plant is exposed to considerable risk from the amount of suspended solids in first flush of storm sewage.

Instead of separate storm water beds, would prefer to provide a larger number of contact beds, and distribute on them, after screening and settlement, the whole volume which comes to the works.

From a practical point of view, thinks that storm sewage, when fully diluted, might be sufficiently purified by settlement, without chemicals or subsequent filtration. Even the first dilutions would be sufficiently dealt with by settlement. (23798–23800).

24252 *Mr. Wilkinson* (*Manchester*): Suggests as follows:—

(1) At all times—Two volumes of the mixed sewage and storm water to be treated in the ordinary plant.

(2) For 16 hours out of 24—Two volumes of the mixed sewage and storm water through ordinary plant, and the balance up to six volumes through storm water filters.

(3) For remaining 8 hours—Two volumes of sewage and rain water through ordinary plant, and remainder by settlement in special tanks.

24306 Thinks that treatment of six volumes in storm times is the highest practicable economic limit

24945 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): Settlement alone in properly designed tanks would generally be sufficient for whole flow of sewage and storm water after first flush (say after two hours). Storm water filters are inefficient and costly, and the intermittent recurrence of rain does not warrant the provision of expensive works for treating a volume which may only reach the works at long intervals.

25207 Estimate that storage (settlement in tanks) for 10,000,000 gallons would cost £50,000.

25214 Only four dilutions need be provided for in the case of a large drainage area.

25222 Not practicable for any authority to deal with the whole of the storm water.

26016 *Messrs. Willcox & Raikes*: As polluting matter in storm sewage chiefly consists in suspended solids, it would be sufficient to remove these by simple settlement in tanks or rapid straining through fine filters of shallow depth.

26144–7 Provision for treatment of more than three times the dry-weather flow hardly seems necessary. At Hanley that amount was only exceeded on thirty-one occasions in a year, viz.: on twelve occasions for half an hour, eleven occasions for one hour, and on eight occasions for periods from one to three hours.

26149–59 It is not found in practice that separate filters for excess storm water are beneficial. It is preferable to provide increased area of filters and use them regularly in rotation all the year round for treating the ordinary flow of sewage with an accelerated rate in storm times.

STORM WATER SEWAGE.

(5.) WHAT IS THE INCREASE IN VOLUME ON THE DRY-WEATHER FLOW DURING THE YEAR, IF STORM WATER UP TO FIVE DILUTIONS IS DEALT WITH AT THE WORKS.

Interim Report: Vol. II. (*Cd.* 686), 1902.

1771. *Mr. Santo Crimp*: Increase would be from 20 to 30 per cent.

7528-30 *Mr. G. R. Strachan*: Total increase in year would possibly be an addition of $\frac{1}{7}$ or $\frac{1}{8}$ of volume of dry-weather flow. No overflow in the sewers in the case on which this calculation is based: all storm water went to the pumping station.

Fifth Report: Appendix I.

23050–2 *Mr. Fowler* (*Manchester*): Generally speaking, 50 per cent. on dry-weather flow.

25225. *Messrs. Watson & O'Shaughnessy* (*Birmingham*): Would think that the increase would be about 30 per cent. on dry-weather flow.

(6.) WOULD IT BE POSSIBLE TO HAVE A STANDARD FORM OF STORM OVERFLOW, AND HOW SHOULD THE POINT BE FIXED AT WHICH OVERFLOWS SHOULD BE ALLOWED TO COME INTO OPERATION. STORM WATER SEWAGE.

Interim Report: Vol. II. (*Cd.* 686), 1902.

1631-3 *Mr. Santo Crimp*: The point at which overflow should come into operation ought to depend upon the nature of the stream into which the overflow would pass: five dilutions, where the overflow is into (say) tidal waters, and 8 or 10 dilutions where into a small stream of pure water. The point of overflow should be arranged with regard to a certain number of gallons per head of the population, rather than with regard to a certain number of dilutions of the total dry-weather flow; 150 gallons per
1790-4 head would be a safe minimum.

6251-4 *Dr. Maclean Wilson:* Overflow should be fixed as high as financially practicable. At not less than five dilutions in any case.

6460 *Mr. G. Chatterton:* Suggests that overflow should be fixed at five dilutions.

6657-8 *Mr. R. A. Tatton*: Point at which overflow should operate depends on circumstances; but thinks, generally, that six volumes would be fair amount to treat. Should be based on the maximum dry-
6824-6 weather flow, not on the average.

7541 *Mr. G. R. Strachan*: Overflow should be fixed with regard to certain number of gallons per head of population. Would not go below 120 gallons per head, and would prefer 150.

Fifth Report: Appendix I.

21599 *Mr. Campbell* (*Huddersfield*): Not possible to have standard form of overflow.

22405 *Mr. Valentine* (*Oldham*): Sees no advantage in a standard form of overflow. Would prefer a moveable sluice at the outfall works.

STORM WATER SEWAGE.

(6.) Would it be possible to have a Standard Form of Storm Overflow, and how should the Point be fixed at which Overflows should be allowed to come into Operation (*continued*).

22599 *Dr. Wilkinson* (*Oldham*): Possibly in some places where there is a very regular flow; but in large towns, with an experienced man in charge, it would be much better to regulate the overflow according to the condition of the sewage.

23200 *Mr. Carter Bell* (*Salford*): Not in the case of Salford.

23509 *Mr. Wike* (*Sheffield*): Standard form of overflow not practicable, as nature of each overflow and point at which it comes into operation must depend upon the particular circumstances.

24254 *Mr. Wilkinson* (*Manchester*): Not possible to have an absolutely standard form of overflow. Describes essential features of a properly constructed complete overflow.

Local overflows in the town should as a rule dilute sewage flow with five volumes of rain at the maximum flow; this should be exceeded rather than otherwise. The difference should be adjusted at a main overflow below point of connection of last tributary sewer.

24947 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): Yes: point should be fixed upon the basis of a certain number of dilutions of the dry-weather flow, based upon the average dry-weather flow.

26018 *Messrs. Willcox & Raikes*: Not desirable to have a standard form of overflow because of widely varying conditions. In most cases, however, overflows might come into operation when the flow exceeds three times the *maximum* dry-weather flow.

(7.) SHOULD THE POINT AT WHICH STORM OVERFLOWS COME INTO OPERATION DEPEND ON THE CONFIGURATION OF THE LAND AND UPON THE CHARACTER OF THE SURFACE SOIL GEOLOGICALLY.

Fifth Report : Appendix I.

20726 *Messrs. Raymond Ross & Pickles* (*Burnley*) : Not necessary. Overflows should be fixed at six dilutions independently of characteristics.

21093 *Mr. Bolton* (*Heywood*) : Does not think it possible to arrange a fixed overflow to suit varying conditions.

21424 *Mr. Kershaw* (*Rotherham*) : Storm overflows might be allowed to come into operation sooner in hilly districts than in flat, as in the former the sewage passes to the outfall more rapidly.

21600 *Mr. Campbell* (*Huddersfield*) : No : better to fix overflows to a certain fixed volume of flow independent of configuration and character of ground.

22405 *Mr. Valentine* (*Oldham*) : Yes ; and generally upon the circumstances of the particular district.

22600 *Dr. Wilkinson* (*Oldham*) : Yes, certainly.

23510 *Mr. Wike* (*Sheffield*) : Configuration of the land a most important factor in fixing the point of dilution for storm overflows.

24255 *Mr. Wilkinson* (*Manchester*) :—The character of the soil geologically is not very important. Each overflow should be the subject of careful supervision, and the point at which it is to come into operation should be carefully settled in each case. Important to have regard to the circumstances of the district, *e.g.*, the nature of the paving of roads.

24948 *Messrs. Watson & O'Shaughnessy* (*Birmingham*) : No .

26019 *Messrs. Willcox & Raikes* : Not practicable to take the configuration or surface geology of the land as the only governing factor. There are many important considerations besides these (26164–7).

(8.) SHOULD STORM OVERFLOWS BE FIXED OR MOVEABLE.

Interim Report: Vol. II. (*Cd.* 686). 1902

1098–1104 *Dr. Maclean Wilson*: Fixed.

6479–81 *Mr. G. Chatterton*: Would fix the overflow after the actual flow had been ascertained.

6654 *Mr. R. A. Tatton*: Fixed, as a rule.

6871–3 *Mr. D. Balfour*: Overflows on line of sewers should be fixed, but at outfall it should be moveable. Recognises the likelihood of moveable overflow being abused, but thinks there must be some means of preventing large volume of water going on land when the land may be already saturated.

7680 *Mr. G. R. Strachan*: Always takes care that principal overflow at sewage works is fixed.

Fifth Report: Appendix I.

20727 *Messrs. Raymond Ross & Pickles* (*Burnley*): Sills should be fixed, but capable of being raised if and when increase of normal flow necessitates.

21094 *Mr. Bolton* (*Heywood*): Under sound and reliable control, a moveable overflow would be most satisfactory for general conditions.

21425 *Mr. Kershaw* (*Rotherham*): Fixed.

(8.) Should Storm Overflows be fixed or moveable (*continued*).

21601 *Mr. Campbell* (*Huddersfield*): Fixed

22105 *Mr. Valentine* (*Oldham*): Would prefer the moveable form at the outfall works.

22601 *Dr. Wilkinson* (*Oldham*): Moveable, in large works. Because the earlier flow is very polluted, whereas the latter flow is very weak and could be passed direct to river (22702).

23201 *Mr. Carter Bell* (*Salford*): Fixed.

23511 *Mr. Wike* (*Sheffield*): Fixed, but of such construction that it can be easily adjusted to suit an increasing quantity of sewage (normal flow).

24256 *Mr. Wilkinson* (*Manchester*): Fixed, as a general rule, except where tributary sewer drains undeveloped land on which population is increasing; in such cases should be capable of adjustment to meet changed conditions.

Last overflow on leaving town at upper end of main outfall sewer should be absolutely fixed.

24949 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): Storm overflows should be adjustable, so as to meet increases in the flow of sewage from year to year.

26020 *Messrs. Willcox & Raikes*: Storm overflows should be adjustable to meet any material increase in volume of sewage; but should be so secured that no alteration can be made by unauthorised persons. Fixed overflows are not convenient (26168).

STORM WATER SEWAGE.

(9.) SHOULD THE NUMBER OF DILUTIONS AT WHICH STORM SEWAGE MAY PROPERLY BE ALLOWED TO PASS INTO A STREAM BE DEPENDENT UPON THE SIZE AND NATURE OF THE STREAM.

Fifth Report : Appendix I.

20728 *Messrs. Raymond Ross & Pickles* (*Burnley*): Yes, especially with reference to the rate of increase in the volume of stream and its velocity in storm times. In some cases, when road washings have once been disposed of, the whole volume of storm sewage might be discharged into a stream without injury to the stream.

20990- The number of dilutions should be determined, if possible, by mutual arrangement between rivers board and local authority. In cases of dispute, there should be reference to central authority.

21095 *Mr. Bolton* (*Heywood*): Thinks that there should be differentiation between towns on tidal rivers and inland towns. There are no rivers which would not suffer from first rushes of storm water.

21426 *Mr. Kershaw* (*Rotherham*): Yes.

21602 *Mr. Campbell* (*Huddersfield*): Yes.

22406 *Mr. Valentine* (*Oldham*): Whatever the conditions of the stream, the storm sewage discharged into it should be in good condition : it should have no odour of sewage, it should pass the incubator test, and it should have practically no coarse suspended matter—the greater portion of the suspended matter should be of an inorganic nature.

22602 *Dr. Wilkinson* (*Oldham*): The point at which storm sewage should be allowed to pass directly into a stream should depend upon the relative size of the volume of the stream, to the amount of sewage to be discharged into it, and upon the rapidity of the flow in the stream.

22743 *Mr. Fowler* (*Manchester*): Yes, the conditions at the outfall should in all cases be studied. The amount of impurity which can be discharged depends (*a*) on the power of the stream to carry matter in suspension, and (*b*) the available dissolved oxygen in the stream. Greater strictness is required where the stream supports fish life or is a source of water supply.

23202 *Mr. Carter Bell* (*Salford*): Certainly, the storm overflow should depend on the circumstances.

(9.) Should the Number of Dilutions at which Storm Sewage may probably be allowed to pass into a Stream be Dependent upon the Size and Nature of the Stream (*continued*). STORM WATER SEWAGE.

23512 *Mr. Wike (Sheffield)*: Yes.

24257 *Mr. Wilkinson (Manchester)*: Yes, to some extent; but the limits of variation are small. Seems to think that dilution by five volumes at time of maximum flow should generally be required, this being the lowest limit consistent with the protection of the stream from putrescible and suspended matter. Only under special circumstances (described) can volume be varied.

24676 *Dr. Letts*: Yes.

24950 *Messrs. Watson & O'Shaughnessy (Birmingham)*: Yes: each case should be taken on its merits.

26021 *Messrs. Willcox & Raikes*: Generally speaking, yes; but, as a general rule, no untreated storm sewage below three times the *maximum* dry-weather flow should be allowed to pass to a river.

STORM WATER SEWAGE.

(10.) SHOULD THE SURFACE WATER FROM ROADS BE PURIFIED.

Fifth Report: Appendix I.

20732 *Messrs. Raymond Ross & Pickles (Burnley)*: The first portions of storm water should be purified unless the size and volume of river renders this unnecessary.

21098 *Mr. Bolton (Heywood)*: Yes, some simple treatment, as, for example, settlement in tanks.

21429 *Mr. Kershaw (Rotherham)*: Yes.

22407 *Mr. Valentine (Oldham)*: Yes, decidedly so, the first portion washed down by a storm.

22603 *Dr. Wilkinson (Oldham)*: The first washings from a street is an exceedingly polluted liquid.

23205 *Mr. Carter Bell (Salford)*: Yes.

23515 *Mr. Wike (Sheffield)*: Yes, where it comes from streets in which there is heavy traffic or market refuse.

23848-8 Road water at Sheffield very polluting.

24259 24954 *Mr. Wilkinson (Manchester) Watson & O'Shaughnessy (Birmingham)*: The first flush should be purified.

24432 (p. 574.) *Dr. Reid*: Road drainage in populous towns is highly polluting, and should be subjected to at least partial subsidence.

26035 *Messrs. Willcox & Raikes*: Surface water from paved spaces such as markets should be purified; but ordinary street washings may usually be discharged directly into natural watercourses.

(11.) WHAT ARE THE COMPARATIVE COST AND ADVANTAGES OF THE SEPARATE AND COMBINED SYSTEMS OF SEWERS.

STORM WATER SEWAGE.

Fifth Report: Appendix I.

20733 *Messrs. Raymond Ross & Pickles* (*Burnley*): Necessary that some portion of rain water should flow into the sewers. In most circumstances a partially separate system of sewers is desirable. But there must be some storm water admitted for flushing the sewers (21007).

A partially separate system at Burnley cost about one-fifth more than if a combined system alone had been constructed. Annual cost of maintenance of surface drains is very small compared with that of sewerage system.

21603 *Mr. Campbell* (*Huddersfield*): No general rule can be fixed. Whether one system or the other is adopted depends on method of treatment, *e.g.*, the separate system would seem preferable if the sewage were treated chemically as there would be a smaller amount to be treated (21724).

22408 *Mr. Valentine* (*Oldham*): Has no practical knowledge, but, theoretically, the combined system is preferable. The first portion of road water ought to be purified, and, apart from this, filters work better if occasionally filled with settled or precipitated dilute sewage.

22745 *Mr. Fowler* (*Manchester*): The separate system is impracticable in large towns; first flush of storm must be treated in any case, and there is therefore no advantage in incurring the great cost of duplication of sewers. In villages and country districts where there is little traffic and the surface water is not very foul, a separate system could be provided with advantage, since the treatment of the sewage would be enormously simplified, the great difficulty being at sewage works to deal with the ever varying volume and concentration of the sewage in wet weather.

23206 *Mr. Carter Bell* (*Salford*): Separate system has great advantages for scantily populated areas, but for town areas the combined system is always preferable. In the respective cases, economy is best secured by the different systems. Main consideration for this view is that it would be too costly to establish a separate system in towns which have already been sewered on combined system (23296–8).

23516 *Mr. Wike* (*Sheffield*): Generally speaking, a separate system would be more advantageous in a flat district than in a hilly one, and it would probably be more economical where a new scheme was being laid out. In an old town, the cost of a separate system would be prohibitive.

24200 *Mr. Wilkinson* (*Manchester*): Generally speaking, combined system is preferable in urban areas. First portion of road water is of polluting character and ought to be purified; there is also the necessity for flushing the sewers thoroughly. In residential districts and rural areas the separate system offers advantages, provided sufficient rainwater is admitted to foul sewers to keep them clean. The separate system would also offer advantages where pumping has to be resorted to, by minimising volume to be pumped. No fixed rule can, however, be laid down. Separate system would generally entail an increase of 33 per cent. in initial cost.

STORM WATER SEWAGE.

(11.) What are the Comparative Cost and Advantages of the Separate and Combined Systems of Sewers (*continued*).

24955 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): In urban districts a combined system is warranted on economical and sanitary grounds. In suburban and rural districts a separate system is generally justified.

26026 *Messrs. Willcox & Raikes*: Separate system is usually the more costly in initial expenditure, but is far more satisfactory and the cost of maintenance is usually less where road detritus is excluded from sewers.

(12.) WHAT TIME IS NECESSARY TO GAIN A GOOD TANK LIQUOR CONTAINING, SAY, NO MORE THAN SIX TO EIGHT PARTS PER 100,000 OF SUSPENDED SOLIDS (WITHOUT THE ADDITION OF CHEMICALS) (1) BY QUIESCENT SETTLEMENT; (2) BY CONTINUOUS FLOW SETTLEMENT.

SEDIMENTATION.

Fifth Report: Appendix I.

21606 *Mr. Campbell* (*Huddersfield*): Eight hours by continuous flow.

21975 *Mr. Harrison* (*Leeds*): Generally speaking, two hours quiescent settlement will reduce the suspended solids to eight to ten parts per 100,000; with continuous settlement, about a twelve hours rate of flow is required.

22410 *Mr. Valentine* (*Oldham*): About fifteen hours by continuous flow settlement.

22606 *Dr. Wilkinson* (*Oldham*): Probably six or eight hours, by continuous flow settlement.

22748 *Mr. Fowler* (*Manchester*): Generally speaking, two hours for quiescent settlement, and four hours for continuous flow.

23518 *Mr. Wike* (*Sheffield*): Two to three hours by quiescent settlement. Eight to twelve hours by continuous flow settlement, provided that the sludge be removed frequently from the tanks.

24958 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): Eight to ten hours by continuous flow. Less time for quiescent settlement.

26029 *Messrs. Willcox & Raikes*: Seldom possible to reduce to six or eight parts per 100,000 by settlement alone.

SEDIMENTATION TANKS.

(13.) SHOULD SETTLEMENT TANKS BE USED IN SERIES OR IN PARALLEL.

Fifth Report : Appendix I.

21101 *Mr. Bolton* (*Heywood*) : Prefers to use tanks in parallel, thus getting a divided quantity of sewage in each tank and consequently a more gentle flow.

21434 *Mr. Kershaw* (*Rotherham*) : Would say that tanks in series give best results. (Has not worked on other system : this is merely a general opinion : 21555.)

21607 *Mr. Campbell* (*Huddersfield*) : In parallel. This method provides for more equal distribution of sludge (21907).

21975A *Mr. Harrison* (*Leeds*) : With continuous flow, prefers tanks in parallel series of three or four : with quiescent flow, in parallel.

22411 *Mr. Valentine* (*Oldham*) : Would prefer a combination of both, one large tank to receive the combined liquor from tanks used in parallel. No practical experience, however.

22607 *Mr. Wilkinson* (*Oldham*) : Personally would prefer tanks divided by a cross wall into two.

22749 *Mr. Fowler* (*Manchester*) : In parallel. Beyond a certain length of tank there is little additional settlement, and there is greater difficulty in cleaning the tanks one after the other (22907).

23210 *Mr. Carter Bell* (*Salford*) : In parallel. (No particular reason for this : 23304.)

23519 *Mr. Wike* (*Sheffield*) : In parallel.

24959 *Messrs. Watson & O'Shaughnessy* (*Birmingham*) : In parallel.

26030 *Messrs. Willcox & Raikes* : Where slow velocity is required tanks should be worked in parallel rather than in series.

(14.) IS THERE ANY ADVANTAGE IN THE EMPLOYMENT OF BAFFLING BOARDS OR WALLS IN THE CASE OF CONTINUOUS FLOW TANKS.

Fifth Report : Appendix I.

21102 *Mr. Bolton* (*Heywood*): Has found no advantage in baffling walls. They are a source of considerable inconvenience during sludging operations.

21435 *Mr. Kershaw* (*Rotherham*): Baffle walls not of much service; but scum boards should be provided.

21608 *Mr. Campbell* (*Huddersfield*): Slight advantage in baffling boards; they prevent sludge accumulating at outlet end.

22412 *Mr. Valentine* (*Oldham*): Does not see much advantage.

22750 *Mr. Fowler* (*Manchester*): Yes: baffling boards keep back much of the floating grease, and, if made deep, tend to prevent surface currents. A submerged wall at the inlet facilitates separation of grit from the sludge proper.

23211 *Mr. Carter Bell* (*Salford*): Yes.

23520 *Mr. Wike* (*Sheffield*): Yes; the walls retain the heavy detritus at one end and facilitate sludging.

24960 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): Yes, of considerable use.

26031 *Messrs. Willcox & Raikes*: No.

SEDIMENTATION TANKS.

(15.) SHOULD THE HEAVY PORTION OF THE SUSPENDED MATTER IN SEWAGE (ROAD DETRITUS, &c.) BE REMOVED AS A FIRST OPERATION, OR IS IT BETTER AND MORE ECONOMICAL TO LET EVERYTHING SETTLE IN THE TANKS, AND SUBSEQUENTLY TO SCREEN THE SLUDGE.

Fifth Report : Appendix I.

21104 *Mr. Bolton (Heywood)* : Far better to remove heavy road detritus as a first operation, especially where sludge has to be pumped. Advantageous in any case.

21437 *Mr. Kershaw (Rotherham)* : Prefers to keep road detritus out of tanks as far as possible.

21610 *Mr. Campbell (Huddersfield)* : All grit should first be removed

21976 *Mr. Harrison (Leeds)* : At Leeds the road detritus, etc., is settled out in the tanks.

22414 *Mr. Valentine (Oldham)* : Would prefer the removal of the road detritus, etc., as a first operation, and thinks it would be more economical than the other plan.

22610 *Dr. Wilkinson (Oldham)* : Road detritus, ashes, etc., are best removed by preliminary detritus tanks.

22752
22909-10 *Mr. Fowler (Manchester)* : In general, sludge can be successfully screened ; but where sewage contains much cotton waste or other fibrous material, it is necessary first to screen the sewage.

23213 *Mr. Carter Bell (Salford)* : At Salford detritus, etc., is first arrested.

23522 *Mr. Wike (Sheffield)* : 24678 *Dr. Letts* : The road detritus, etc., should first be removed.

(15.) Should the Heavy Portion of the Suspended Matter in Sewage (Road Detritus, etc.), be Removed as a First Operation, or is it better and more Economical to let everything Settle in the Tanks, and subsequently to Screen the Sludge (*continued*).

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32 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): Better to let everything settle and subsequently screen the sludge. At the same time, more economical to insert partition walls to separate maximum amount of road detritus.

SEDIMENTATION TANKS.

(16.) IS THERE ANY NUISANCE FROM [THE TREATMENT OF SEWAGE IN SETTLEMENT TANKS.

Fifth Report: Appendix I.

21613 *Mr. Campbell (Huddersfield)*: No.

21440 *Mr. Kershaw (Rotherham)*: Slight smell at times, but notbing serious.

22417 *Mr. Valentine (Oldham)*: No.

22612* *Dr. Wilkinson (Oldham)*: No.

22755 *Mr. Fowler (Manchester)*: No.

23216 *Mr. Carter Bell (Salford)*: No.

23525 *Mr. Wike (Sheffield)*: No.

24965 *Messrs. Watson & O'Shaughnessy (Birmingham)*: No nuisance; but more smell from settlement tanks than from septic tanks.

26036 *Messrs. Willcox & Raikes*: No.

(17.) IS SEWAGE FROM WHICH THE SOLIDS HAVE BEEN REMOVED BY THE AID OF CHEMICALS LESS EASILY PURIFIED BY SUBSEQUENT FILTRATION THAN SEWAGE FROM WHICH THE SOLIDS HAVE BEEN REMOVED BY SETTLEMENT OR BY PASSAGE THROUGH SEPTIC TANKS.

CHEMICAL PRECIPITATION.

Interim Report: Vol. II. (*Cd.* 686), 1902.

4217 *Dr. S. Rideal:* Lime has a sterilising action, with the result that there is absence of nitrification in the
4476-8 subsequent filtration.

4895-6 *Mr. C. J. Whittaker:* Lime is necessary at Accrington to neutralise the acidity of the sewage. Abstention from lime led to unsatisfactory results.

Fifth Report: Appendix I.

20735 *Messrs. Raymond Ross & Pickles* (*Burnley*): Obtained better results from contact beds with septic tank liquor than with chemically precipitated sewage. Both speak positively on this point: chemicals
20836-57 used for precipitation caused deposit of iron in beds which was detrimental to them.

Have made no simultaneous experiments for purpose of ascertaining comparative results. Answers based on albuminoid ammonia figures.

21106 *Mr. Bolton* (*Heywood*): At Heywood a chemically precipitated sewage was more easily treated in the contact beds than a septic tank liquor.

21442 *Mr. Kershaw* (*Rotherham*): No.

21615 *Mr. Campbell* (*Huddersfield*): No, equally good results are obtained with a chemically precipitated effluent as with a septic tank liquor.

21978 *Mr. Harrison* (*Leeds*): Recent experiments show that an effluent, produced by using eight grains of lime per gallon and two grains of sulphate of alumina and practically free from suspended matter, can be
22122-4 treated more easily in trickling filters than septic tank or settled sewage. (Comparative analytical figures are given.) Analytical results with chemically precipitated sewage are better and a greater quantity per cubic yard can be treated (100 gallons of precipitated sewage against sixty-one gallons of septic tank effluent).

CHEMICAL PRECIPITATION.

(17.) Is Sewage from which the Solids have been Removed by the aid of Chemicals less easily Purified by Subsequent Filtration than Sewage from which the Solids have been Removed by Settlement or by Passage through Septic Tanks (*continued*).

22419 *Mr. Valentine (Oldham)*: A sewage, especially a strong one, treated reasonably with chemicals is more easily purified by subsequent filtration than the same sewage subjected to settlement only. Is inclined,
22514 however, to prefer a septic liquor to either. The solid matter in the sewage is the difficulty in the way of purification.

22614 *Dr. Wilkinson (Oldham)*: Generally, simple settled sewage gave a better result than that precipitated by chemicals. A septic effluent, if not containing too many solids, gives a better result than either.

22757 *Mr. Fowler (Manchester)*: Assuming the same amount of suspended matter, and the same character of filtering medium, thinks that rather better results are obtained from septic tank liquor. Much better results were obtained at Manchester from septic tank liquor and double contact than from settled sewage and double contact; and the coke and clinker experimental filters treating precipitated and settled sewage never produced nitrates as in the case of the beds receiving septic tank liquor. No strictly comparable experiments have, however, been made by him.

23527 *Mr. Wike and Mr. Haworth (Sheffield)*: Experiments at Sheffield in the treatment in contact beds of lime
23640-1 precipitated sewage were practically a failure. The alkalinity of the limed effluent would seem to have sterilised the beds.

24432 (p. 574) *Dr. Reid*: If anything, chemically treated sewage is more readily purified by subsequent filtration. In some cases (*e.g.*, where sewage contains galvanisers' waste) chemical treatment is essential.

24967 *Messrs. Watson & O'Shaughnessy (Birmingham)*: No difficulty found in filtration of chemically precipitated sewage.

25829 *Mr. F. Scudder*: Got excellent results from the treatment of chemically precipitated effluent in percolating filters. Equally good results with settled sewage. Not such good results with septic tank effluent.

26038 *Messrs. Willcox & Raikes*: Found that chemically (lime) treated liquor had a tendency to clog the land filters at Hanley; the land was practically converted into concrete (26312).

(18.) WHAT IS THE MOST EFFECTIVE WAY OF ADDING CHEMICALS TO SEWAGE.

Fifth Report : Appendix I.

21108 *Mr. Bolton* (*Heywood*) : In solution of known strength.

21444 *Mr. Kershaw* (*Rotherham*) : In solution.

21617 *Mr. Campbell* (*Huddersfield*) : Lime should be added as milk of lime, and applied from five to ten minutes in advance of copperas.

21980 *Mr. Harrison* (*Leeds*) : Lime is best added in form of lime water, where practicable. Where not practicable weak milk of lime should be used. Other chemicals should be used in solution where possible.

22421 *Mr. Valentine* (*Oldham*) : By dissolving (or diluting in the case of lime) the chemicals. In this way, the addition is easily controlled, according to the varying strength and volume of the sewage.

22616 *Dr. Wilkinson* (*Oldham*) : At Oldham, lime is added as lime-water, and the copperas in solution. The amount applied varies automatically with the flow of sewage.

22759 *Mr. Fowler* (*Manchester*) : In solution, with moderate mixing by baffling boards or otherwise.

23219 *Mr. Carter Bell* (*Salford*) : Lime as milk of lime, and the copperas afterwards, in solution.

23529 *Mr. Wike* (*Sheffield*) : In the form of milk of lime, after being well mixed with sewage and churned.

(18.) WHAT IS THE MOST EFFECTIVE WAY OF ADDING CHEMICALS TO SEWAGE (*continued.*)

24432 (p. 574) *Dr. Reid*: In soluble form.

24969 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): Thorough amalgamation of milk of lime with sewage before it enters tank. Milk of lime can be shot into the sewer.

26040 *Messrs. Willcox & Raikes*: Thorough mixing is essential, either by passing through pumps, mechanical mixers, or other means.

(19.) IS IT NECESSARY TO ADD FURTHER CHEMICALS TO THE SLUDGE FROM PRECIPITATION TANKS FOR THE PURPOSE OF PRESSING OR OTHERWISE.

Fifth Report: Appendix I.

21111 *Mr. Bolton* (*Heywood*): Yes, to keep it porous and to prevent it sticking to the sheets. Lime is used in small quantity (1·2 per cent.) prior to the sludge being passed into ejectors.

21446 *Mr. Kershaw* (*Rotherham*): Lime is necessary for pressing sludge. It should be added in form of dry powder in the mixing vessel.

21620 *Mr. Campbell* (*Huddersfield*): Yes, lime is added to render sludge more manageable. Lime is slaked and made into a cream with water and run into the ram with the sludge.

21982 *Mr. Harrison* (*Leeds*): Not where the sludge is dried in lagoons.

22618 *Dr. Wilkinson* (*Oldham*):
22423 *Mr. Valentine* (*Oldham*): } It is necessary to add lime to the sludge to kill the grease, before it will press readily. Slaked lime is added and mixed by manual labour.

22762 *Mr. Fowler* (*Manchester*): Yes. Lime is added to the amount of 2 per cent. on the wet sludge in order to obtain a coherent cake. Added in form of powdery slaked lime by manual labour.

23221 *Mr. Carter Bell* (*Salford*): Not at Salford: sludge is sent to sea.

23531 *Mr. Wike* (*Sheffield*): No.

24432 (p. 574) *Dr. Reid*: Addition of lime facilitates the process of pressing, and enables a drier and firmer cake to be formed.

(19.) Is it Necessary to add Further Chemicals to the Sludge from Precipitation Tanks for the Purpose of Pressing or Otherwise (*continued*).

24972 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): No. (Sludge pumped to land, not pressed.)

26048 *Messrs. Willcox & Raikes*: Where sludge is pressed, additional lime is required to counteract glutinous or greasy matter which would clog the filter cloths in the presses.

(20.) IS THERE ANY NUISANCE FROM THE TREATMENT OF SEWAGE IN CHEMICAL PRECIPITATION TANKS.

CHEMICAL PRECIPITATION.

Fifth Report: Appendix 1.

20740* *Messrs. Raymond Ross & Pickles (Burnley)*: No.

21113 *Mr. Bolton (Heywood)*: Offensive smell during sludging operations, but not at other times.

21449 *Mr. Kershaw (Rotherham)*: Ordinarily, no.

21623 *Mr. Campbell (Huddersfield)*: No.

21986 *Mr. Harrison (Leeds)*: Not from the tanks, but from the drying of the sludge in lagoons.

22425 *Mr. Valentine (Oldham)*: No.

22621 *Dr. Wilkinson (Oldham)*: No.

22765 *Mr. Fowler (Manchester)*: No.

3534 *Mr. Wike (Sheffield)*: No

4432 (p. 574) *Dr. Reid*: No.

CHEMICAL PRECIPITATION.

(20.) Is there any Nuisance from the Treatment of Sewage in Chemical Precipitation Tanks (*continued*).

24975 *Messrs. Watson & O'Shaughnessy (Birmingham)*: Not from the treatment itself, but from the sludge.

26046 *Messrs. Willcox & Raikes*: No.

(21.) HOW SHOULD SEPTIC TANKS BE SHAPED.

SEPTIC TANKS

Interim Report; Vol. II. (Cd. 686), 1902.

7248 *Col. Harding:* Shape of tank not important.

Fifth Report: Appendix I.

20741 *Messrs. Raymond Ross & Pickles (Burnley):* Have found rectangular-shaped tanks (eighty feet by forty-six feet by six feet six inches) convenient.

21114 *Mr. Bolton (Heywood):* Rectangular; length about four times the width.

21450 *Mr. Kershaw (Rotherham):* Oblong, and arranged so that sewage flows in direction of greatest length (no actual experience of septic tank treatment: 21549–50.)

21624 *Mr. Campbell (Huddersfield):* Long, rectangular.

21987 *Mr. Harrison (Leeds):* Rectangular, and from six to eight feet deep. Outlet should draw off below water level.

It is preferable to have the flow across the short width of tank.

22622 *Dr. Wilkinson (Oldham):*
22426 *Mr. Valentine (Oldham):* Rectangular; and the floor sloped to the entrance so that part of the sludge can be drawn off from time to time without emptying the tank.

22766 *Mr. Fowler (Manchester):* Prefers long rectangular tank, so constructed that sludge can be removed from both inlet and outlet ends.

SEPTIC TANKS.

(21.) How should Septic Tanks be shaped (*continued.*)

23535 *Mr. Wike* (*Sheffield*): Long, rectangular, with the floor sloping to the inlet end in order to facilitate removal of sludge

24261 *Mr. Wilkinson* (*Manchester*): Long rectangle in the direction of the flow is best shape.

24432 (p. 574) *Dr. Reid*: Longitudinal.

24976 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): Rectangular tanks work very well; but some observations upon a Dortmund tank (inverted cone shape) indicate that it is well adapted for septic treatment and
25048 possesses marked advantages over rectangular form. The essential advantage is that a relatively large surface is exposed for the reception of the lighter organic sludge.

26047 *Messrs. Willcox & Raikes*: Best results have been obtained when capacity equals daily dry-weather flow, and width is about one-third length; but these proportions must depend largely on capacity and velocity required.

(22.) SHOULD SEPTIC TANKS BE DIVIDED INTO SECTIONS.

Fifth Report: Appendix I.

20742 *Messrs. Raymond Ross & Pickles (Burnley)*: Know of no advantage in dividing tanks into sections.

21115 *Mr. Bolton (Heywood)*: Not the tank itself. A grit chamber should be built at the inlet end unless catch pits are provided

21451 *Mr. Kershaw (Rotherham)*: Not necessary, except for facilitating sludging (no actual experience of septic tank treatment: 21549–50.)

21625 *Mr. Campbell (Huddersfield)*: If they are not of good length, tanks should be divided into sections to lacken flow.

22427 *Mr. Valentine (Oldham)*: Agrees generally with Dr. Wilkinson; but has had no practical experience of tanks divided into sections.

22623 *Dr. Wilkinson (Oldham)*: Would prefer them either in series or with walls dividing them into sections so that the heavier sludge may be retained in the first tank or section.

22767 *Mr. Fowler (Manchester)*: Useful to provide at least a compartment at inlet and outlet ends for facilitating removal of sludge. Sectional tanks useful also where flow of sewage fluctuates largely.

23536 *Mr. Wike (Sheffield)*: Sunk walls are desirable to prevent sludge being carried forward.

24262 *Mr. Wilkinson (Manchester)*: Dividing tanks into sections reduces to a minimum any disadvantage arising from fluctuation in the amount of flow.

(22.) Should Septic Tanks be divided into Sections (*continued.*)

24432 (p. 574) *Dr. Reid*: Not necessary, where separate detritus tanks are provided

24977 *Messrs. Watson & O'Shaughnessy (Birmingham)*: No data to show that there is advantage. All installations of large size must consist of several tanks to facilitate cleansing.

26048 *Messrs. Willcox & Raikes*: Yes, for convenience in emptying and cleaning, and in order to obtain a fairly uniform depth. The maximum capacity of a tank or section should seldom exceed 500,000 gallons.

(23.) SHOULD SEPTIC TANKS BE USED IN SERIES OR IN PARALLEL.

Interim Report: Vol. II. (*Cd.* 685), 1902.

711-4 *Mr. C. J. Whittaker*: Most convenient to work tanks in series chiefly because it facilitates removal of sludge. Less solids in suspension in both the tank effluent and the final filtrate.

249 *Col. Harding*: Only advantage in working in series is that it facilitates removal of sludge. Leeds did not by this system of working get an effluent more free from suspended solids.

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1116 *Mr. Bolton* (*Heywood*): In parallel.

1452 *Mr. Kershaw* (*Rotherham*): Thinks tanks in series are preferable. (No actual experience of septic tank treatment: 21549–50.)

1626 *Mr. Campbell* (*Huddersfield*): In parallel.

1988 *Mr. Harrison* (*Leeds*): Best used in parallel so as to reduce rate of flow to a minimum. Experiment at Leeds with tanks used in series gave unsatisfactory results, on account of the first tank sludging up rapidly.

(Earlier experiments at Leeds seemed to point to advantage in working in series, as the sludge could be more easily removed. See 14951-5 (*Third Report: Vol. II.*) and Col. Harding's evidence.)

2623 *Dr. Wilkinson* (*Oldham*): Would prefer them either in series or with walls dividing them into sections, so that the heavier sludge may be retained in the first tank or section.

2768 *Mr. Fowler* (*Manchester*): In parallel.

23.) SHOULD SEPTIC TANKS BE USED IN SERIES OR IN PARALLEL (*continued.*)

23537 *Mr. Wike* (*Sheffield*): A single tank of suitable length is sufficient.

24263 *Mr. Wilkinson* (*Manchester*): Preferably in parallel, as uniformity of septic action throughout liquid is secured.

24432 (p. 574) *Dr. Reid*: In parallel.

24978 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): In parallel

26049 *Messrs. Willcox & Raikes*: In parallel, to secure slow velocity.

(24.) IS A SCUM NECESSARY OR DESIRABLE IN A SEPTIC TANK.

Interim Report: Vol. II. (*Cd.* 686). 1902.

643 *Mr. Baldwin Latham*: At Barton, the smell coming from the scum was very disagreeable.

5553–62 *Mr. Fowler* (*Manchester*): Septic tank is always ten degrees hotter than the atmosphere, and the scum is useful in preserving its heat in winter time.

3440-3 *Mr. G. Chatterton*: Had personal experience of an undoubted nuisance arising from the scum in an open septic tank dealing with domestic sewage.

Fifth Report: Appendix I.

20744 *Messrs. Raymond Ross & Pickles* (*Burnley*): Believe a scum is desirable; but do not find that it makes any difference in the purity of final effluents.

20859-62 No strong reason for thinking a scum desirable; but believe it is useful in conserving the heat of the sewage.

21117 *Mr. Bolton* (*Heywood*): Not absolutely necessary, but is desirable. It keeps the smell down and also keeps the lighter solids over whole surface, preventing them from being washed out of tanks before they have been resolved into simpler compounds.

21453 *Mr. Kershaw* (*Rotherham*): Not absolutely necessary. (No actual experience of septic tank treatment. 21549–50.)

21627 *Mr. Campbell* (*Huddersfield*): Not necessary.

22002 *Mr. Harrison* (*Leeds*): No. At Leeds it was found that the scum became broken up in wet weather, and caused heavy increase of suspended matter in tank effluent. The tanks are now kept free from scum and it has not been found that its absence is deleterious.

(24.) Is a Scum Necessary or Desirable in a Septic Tank (*continued*).

22429 *Mr. Valentine* (*Oldham*): Does not think so.

22624 *Dr. Wilkinson* (*Oldham*): Has no practical experience; but is disposed to think that the scum, by forming a cover, may be of assistance and allow greater bacterial growth.

Has made experiments showing that liquefaction takes place more rapidly in the dark.

22769 *Mr. Fowler* (*Manchester*): Not necessary for bacterial action; but useful in maintaining equable conditions and arresting floating fat.

23538 *Mr. Wike* (*Sheffield*): Not that he is aware of.

24263 *Mr. Wilkinson* (*Manchester*): A scum not absolutely necessary, and may be disadvantageous in some cases.

24432 (p. 574) *Dr. Reid*: Does not consider a scum necessary.

24979 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): Efficiency of tank does not appear to depend on presence or absence of scum. A scum may, however, facilitate the conservation of heat to some extent.

26050 *Messrs. Willcox & Raikes*: Not necessary; but sometimes desirable for preventing disturbance of surface by wind.

26991 *Mr. F. W. Stoddart*: The appearance of a true bacterial scum is the first indication of over-putrefaction. A scum is open to objection mainly because of the mechanical troubles which arise in the filter from
27002 4 the detachment of the under surface of the scum which passes away with the liquid. (*See also* 27011-6.)

(25.) SHOULD THE SEPTIC TANK BE COVERED.

Interim Report: Vol. II. (*Cd.* 686). 1902.

4643 *Mr. Baldwin Latham*: If tanks are left open a layer of offensive matter accumulates on surface. At Barton, the smell coming from the top layer was very disagreeable.

4801-3 *Mr. C. J. Whittaker* (*Accrington*): No advantage in covering tank so far as septic action is concerned.

6746 *Mr. R. A. Tatton*: Not much use in a cover, apart from the possibility of consuming the gas.

7245 *Col. Harding*: No appreciable advantage in a closed tank (experience at Leeds), and roofed-in septic tanks may, if not under proper care, become a serious source of danger owing to the gases.

7523 *Mr. G. R. Strachan*: Not much experience, but would prefer a closed tank (apparently for æsthetic reasons). A light roof would not cost much.

8414 *Mr. Fowler* (*Manchester*): Results with open and closed tanks were practically identical.

9927
9945 *Dr. P. F. Frankland*: No difference in results; but covering may be desirable in some cases for avoiding smell and possibility of gas collection.

Fourth Report: Vol. II. (*Cd.* 1884), 1904.

18743 *Dr. Clowes*: Open tanks were quite as satisfactory as closed ones at Crossness.

SEPTIC TANKS.

(25.) SHOULD THE SEPTIC TANK BE COVERED (*continued*).

Fifth Report: Appendix I

20745
20863 *Messrs. Raymond Ross & Pickles* (*Burnley*): Experiments proved conclusively that with Burnley sewage nothing was gained by covering tank; not worth the expense.

21118 *Mr. Bolton* (*Heywood*): Not necessary to cover tank except where it is near dwellings. Covering avoids nuisance from smell.

21454 *Mr. Kershaw* (*Rotherham*): No material advantage in closed tank. (Had no actual experience of septic tank treatment: 21549–50.)

21628 *Mr. Campbell* (*Huddersfield*): No advantage in covering. A cover is costly and dangerous.

21989 *Mr. Harrison* (*Leeds*): Closed tanks possess no advantages over an open one, except possibly in minimising risk of nuisance.

22430 *Mr. Valentine* (*Oldham*): Sees no advantage in a closed septic tank over an open one.

22625 *Dr. Wilkinson* (*Oldham*): Assuming a scum to be of value, the only advantage in a covering for the tank would be the preservation of the scum against the effects of rain, wind, etc.

22770 *Mr. Fowler* (*Manchester*): A cover is not necessary for septic action, and sludging is easier with an open tank. On the other hand, a cover protects the tank from wind and rain; a closed tank is more sightly. and it is possible to minimise any risk of nuisance by the provision of shafts.

23539 *Mr. Wike* (*Sheffield*): Not aware of any advantage to be gained by covering which would warrant the expense.

24264 *Mr. Wilkinson* (*Manchester*): No advantage in a closed tank, except possibly in the way of avoiding nuisance, and minimising surface disturbance in case of large tanks exposed to wind. Cover increases cost from 30 to 50 per cent.

24432 (p. 575) *Dr. Reid*: No advantage in covering tank, except where its position necessitates special precautions against risk of nuisance.

24980 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): Six months' observations of both kinds do not show that closed tank has any appreciable advantage over open tank.

26051 *Messrs. Willcox & Raikes*: Septic action not improved by covering, but possibility of smell is reduced.

SEPTIC TANKS.

(26.) WHAT IS THE BEST ARRANGEMENT FOR THE "FEED" AND "DRAW-OFF" FOR SEPTIC TANKS.

Fifth Report: Appendix I.

20746 *Messrs. Raymond Ross & Pickles (Burnley)*: Admission should be by sealed inlets at deep end of tank, arranged so as to give greatest possible diffusion through tank. Draw-off should consist of sealed outlet and sill running whole width of tank opposite feed.

21119 *Mr. Bolton (Heywood)*: Dipping inlets and bent outlets. (Sketch given.)

21455 *Mr. Kershaw (Rotherham)*: Some form of submerged inlet and outlet desirable. (Had no actual experience of septic tank treatment: 21549–50.)

21629 *Mr. Campbell (Huddersfield)*: The feed should be a few feet below the surface. For "draw-off," there should be a long pipe with slot on under side, the effluent to pass over a lip or sill to allow of aeration.

21990 *Mr. Harrison (Leeds)*: Both methods of feeding, below and at the surface level, answer equally well. The outlet should always be below the surface.

22431 *Mr. Valentine (Oldham)*: Sees no reason why the ordinary "surface" methods should not be used. If, however, the sludge is allowed to accumulate, the "draw-off" should be about eighteen inches below the surface.

22626 *Dr. Wilkinson (Oldham)*: Very little experience; but the "draw-off" must be below the surface, and the feed also, if the tank is to be air-tight.

22771 *Mr. Fowler (Manchester)*: A long submerged sill having in front some form of baffle plate so that a steady flow may be maintained through body of tank

23540 *Mr. Wike (Sheffield)*: Both inlet and outlet should consist of a narrow slit across the whole width of tank, the inlet being well below surface.

(26.) WHAT IS THE BEST ARRANGEMENT FOR THE "FEED" AND "DRAW-OFF" FOR SEPTIC TANKS (*continued*).

SEPTIC TANKS.

24265 *Mr. Wilkinson* (*Manchester*): "Feed" should be by dip pipes or valves delivering midway between surface and bottom. "Draw-off" should be by perforated wall with a channel behind, the openings into the channel being at about quarter the total depth from the surface.

24432 (p.575.) *Dr. Reid*: Both feed and draw-off should be by submerged inlet and outlet extending for whole width of tank.

24981 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): In Dortmund Tank, feed is a large submerged pipe coinciding with axis of cone and discharging vertically downwards. "Draw-off" consists of trough running diametrically across tank

26052 *Messrs. Willcox & Raikes*: In each case a weir extending full width of tank, with scum boards extending, say, two feet below surface of sewage in front of inlet and outlet.

SEPTIC TANKS.

(27.) WHAT IS THE MOST ADVANTAGEOUS RATE OF FLOW THROUGH SEPTIC TANKS. SHOULD THIS DEPEND ON THE STRENGTH OR CHARACTER OF THE SEWAGE.

Interim Report: Vol. II. (*Cd.* 686). 1902.

1895–6 1960 *Mr. D. Cameron* (*Exeter*): Found eighteen to twenty hours' stay in tank produced best condition for filtration. Rate would vary with strength of sewage and temperature, action being more rapid when sewage is concentrated and weather is warm.

7247 *Colonel Harding*: From experiments at Leeds arrives at conclusions :—

(1) Tanks of capacity less than half day's supply are too small to give time for septic conditions to arise.

(2) Twenty-four hours' rate is practical; considers that this is the best rate.

(3) Larger capacity does not give an appreciably better effluent, but may probably bring about a larger digestion of deposit left in tank.

Fourth Report: Vol. II. (*Cd.* 1884). 1904

18748 *Dr. Clowes*: Five or six hours in tank found to be sufficient for subsequent treatment in contact beds. (Experience of small installations in London.) The longer the stay in the septic tank the greater the risk of nuisance.

Fifth Report: Appendix I.

20748 *Messrs. Raymond Ross & Pickles* (*Burnley*): Not much difference within the limits of twelve and twenty-four hours' rate of flow. Suspended matter in effluent greatly increased if flow is too rapid: on the other hand, no advantage in slower rate than twenty-four hours.

21121 *Mr. Bolton* (*Heywood*): The tank should have a capacity equal to twenty-four hours' flow, so as to have uniform flow from the tank. When flow is increased up to three times dry weather rate, sludge is disturbed and portions pass over with the tank liquor, which is decidedly disadvantageous

21631 *Mr. Campbell* (*Huddersfield*): For an average sewage, twenty-four hours' rate is the most advantageous. Any rate below twelve hours is disadvantageous because complete septic action cannot be obtained under twelve hours. A slower rate than twenty-four hours does not produce any better results. Weak sewage can with advantage be passed through at a much greater rate.

(27.) WHAT IS THE MOST ADVANTAGEOUS RATE OF FLOW THROUGH SEPTIC TANKS. SHOULD THIS DEPEND ON THE STRENGTH OR CHARACTER OF THE SEWAGE (*continued*).

21932 *Mr. Harrison* (*Leeds*): A twenty-four hour rate of flow seems to give the best results, from the point of view of the amount of suspended matter in effluent. A slower flow gives very little better results. As the rate of flow is increased above the normal, a larger amount of suspended matter comes away.

Believes that the rate of flow should depend upon the character of the suspended solids in the sewage.

The following are averages of analyses at different rates of flow:—

	12 hour flow.	24-hour flow.	48-hour flow.	24-hour flow.	72-hour flow.
Ammoniacal N.	1·65	1·76	1·82	2·17	2·10
Albuminoid N.	·590	·409	·443	·453	·403
Oxygen absorbed in 4 hours at 80°F.	8·15	6·24	6·10	6·45	5·12
Soluble Solids	97·7	95·3	96·7	90·1	91·4
Suspended Solids	28·0	16·4	15·5	21·7	14·1
	1899–1900 Experiments.			1901–2 Experiments.	

22433-4 *Mr. Valentine* (*Oldham*): From twenty to twenty-four hours, preferably the latter. Would think that there would be disadvantage in a fourteen to sixteen hours rate of flow.

Weak sewage may be passed through tanks more quickly than strong.

22773 *Mr. Fowler* (*Manchester*): Generally speaking, with sewage of a strength of forty gallons per head, about twenty-four hours' flow is desirable, with a greater flow per head (organic matter remaining the same) the rate may be correspondingly quicker, and with a less flow, correspondingly less. Time must be given for settlement of the grosser solids and hydrolysis of the lighter suspended matter.

22979 Is not inclined to allow longer than twenty-four hours.

23542 *Mr. Wike* (*Sheffield*): Rate of flow must depend on strength and character of sewage. From twelve to twenty-four hours should be sufficient. (Has only had experience of small experimental tank at Sheffield).

24267 *Mr. Wilkinson* (*Manchester*): Probably the most advantageous rate is eighteen hours.

24432 (p. 575) *Dr. Reid*: Further experience is required. Personally, thinks that, for ordinary domestic sewage, rate may be from fourteen to sixteen hours.

TANKS.

(27.) What is the Most Advantageous Rate of Flow through Septic Tanks. Should this depend on the Strength or Character of the Sewage (*continued*).

24983 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): Twenty-four hours' rate is found distinctly advantageous for Birmingham sewage. Rate should depend largely on the strength and character of the sewage—stronger sewage requiring the longer time.

26954 *Messrs. Willcox & Raikes*: Results always satisfactory where capacity equals twenty-four hours' flow. Quicker rate increases suspended matter in effluent.

26991 *Mr. F. W. Stoddart*: From experiments at Knowle concludes that the most advantageous rate is one which falls just short of allowing the true bacterial scum to develop. (*See also* 27020–36.)

(28.) IS IT POSSIBLE TO "OVER-SEPTICISE" A SEWAGE.

Interim Report: Vol. II. (Cd. 686). 1902.

2071-5 *Mr. D. Cameron (Exeter)*; Some evidence for thinking that if the sewage is too long in the septic tank —say 36 hours—a nuisance may arise.

3242 *Mr. Scott-Moncrieff*: At Caterham anaerobic action was carried to a point at which the nitrification was completely suspended.

Fourth Report: Vol. II. (Cd. 1884). 1904.

18748 *Dr. Clowes*: Experience of small installations shows that sulphuretted hydrogen is generated if sewage remains too long in tank.

Fifth Report: Appendix I.

20749 *Messrs. Raymond Ross & Pickles (Burnley)*: If sewage be kept too long in tanks, considerable quantities of sulphuretted hydrogen are produced, causing nuisance and interfering with subsequent treatment of the effluent by using up oxygen and interfering with hydrolysis.

21122 *Mr. Bolton (Heywood)*: Where tank is worked too slowly, effluent may give off very offensive odours of sulphuretted hydrogen. Had actual experience of this (21210–1.)

21632 *Mr. Campbell (Huddersfield)*. Yes. The products formed by "over-septicising" are injurious to nitrifying organisms in filters.

21993 *Mr. Harrison (Leeds)*: Has not found it possible to "over-septicise," even with a seventy-two hours' flow. Possibly owing to large amount of iron in Leeds sewage (22048.)

SEPTIC TANKS.

(28.) Is it Possible to Over-septicise a Sewage (*continued*).

22435 *Mr. Valentine* (*Oldham*): Yes, there would probably be an excess of the ultimate products of decomposition, such as sulphuretted hydrogen, carbonic acid, and the simpler organic bodies. Filters have great difficulty in dealing with such a liquid. The "over-septicising" would be brought about by a too slow rate of flow.

22774 *Mr. Fowler* (*Manchester*): Exact information is required. Certain, however, that prolonged retention in tank causes evolution of sulphuretted hydrogen, and consequent production of nuisance.

23543 *Mr. Wike* (*Sheffield*): Yes. When the sewage remains too long in the tank, the effluent is not so suitable for subsequent treatment on contact beds. (Purely an opinion: made no observations: 23637–8.)

23610 *Mr. Haworth* (*Sheffield*): Yes. Sewage which has remained too long in tank is found highly charged with sulphuretted hydrogen and other products of decomposing sludge, and is very difficult to treat on beds.

24432 (p. 575) *Dr. Reid*: No experience of the treatment of over-septicised sewage. But conceives that a nuisance may arise from a too long stay in the tanks.

24984 *Mr. Watson* (*Birmingham*): Yes. (Reasons not given.)

26055 *Messrs. Willcox & Raikes*: If sewage remains stagnant in tank it becomes stale or "over-septicised" and is more difficult to purify. Analyses of filtrate show that organic ammonia and oxygen absorbed are increased.

26991 *Mr. F. W. Stoddart*: His experience has been that where sewage remains in the tank for too long a period secondary (solid) products, differing in nature from ordinary suspended solids of sewage, are formed and these products are the main cause of the clogging of filters. The production of these solids is also coincident with the disengagement of offensive odours when the resulting liquid is exposed. The appearance of a true bacterial scum is the first indication of over-putrefaction.

(29.) WHAT IS THE AMOUNT OF DIGESTION IN A SEPTIC TANK. HOW FAR IS THIS AFFECTED BY THE ATMOSPHERIC TEMPERATURE.

SEPTIC TANKS.

Interim Report : Vol. II. (Cd. 686). 1902.

1903-5 1896 *Mr. D. Cameron (Exeter)* : 80 per cent. of solids appear to be liquefied in tank. Septic action is more rapid when weather is warm.

3179 *Mr. Scott Moncrieff* : Cultivation tank constructed at witness's house resulted in the practical disappearance of sludge, and the experience gained from six other installations provided in 1893 at various places in Surrey and Sussex was invariable as regards the liquefaction of organic matter, and the practical disappearance of sludge.

4135 *Dr. Rideal*: At Exeter the changes produced by the tank included a marked increase in the total solids in solution or fine suspension. A large amount of organic carbon disappears in the tank, as was proved by the fact that the dissolved carbonic acid was greater in the tank effluent than in the raw sewage.

Two series of experiments gave the following results :—

—	Purification effected by Tank.	
	Reduction of Organic Matter measured by Oxygen consumed.	Reduction in Albuminoid Ammonia.
First Series	33 per cent.	54 per cent.
Second Series	25 ,,	38 ,,
Mean	29 ,,	46 ,,

5058-62 *Mr. F. W. Stoddart* : Quotes case where septic tank, capacity half the daily dry-weather flow, dealing with domestic sewage, reduces solids in suspension to 5 parts per 100,000.

5742-54 *Mr. C. J. Whittaker (Accrington)* : Is of opinion that there is no actual digestion of solids in septic tanks, apart from the evolution of gas, which is immaterial. As much sludge is produced as with chemical
5757-66 precipitation. Gives results of actual measurements to support this view.

7254-5 *Col. Harding*: It was estimated that in the No. 1 tank at Leeds with 24 hours' flow there was digestion of 57 per cent. of solids left in tank, equivalent to about 40 per cent. of solids originally in sewage.

SEPTIC TANKS.

(29.) WHAT IS THE AMOUNT OF DIGESTION IN A SEPTIC TANK. HOW FAR IS THIS AFFECTED BY THE ATMOSPHERIC TEMPERATURE (*continued*).

Fifth Report: Appendix I.

20750 *Messrs. Raymond Ross & Pickles* (*Burnley*): No figures available. Slight variations in temperature do not affect digestion.

20919 There is not complete digestion of suspended matter.

21633 *Mr. Campbell* (*Huddersfield*): About 38 per cent. of solids removed by septic process (21726–35).

21994 *Mr. Harrison* (*Leeds*): Average digestion at Leeds 30 per cent. No data as to effect of atmospheric temperature, but, judging from the evolution of gas, thinks it must be considerable.

22298 Taking the gas as the factor, there would seem to be greater septic action in summer than in winter.

22436 *Mr. Valentine* (*Oldham*): No data as to digestion. The character of the effluent is affected to a small extent by changes in atmospheric temperature. Thinks there would be advantage in a slower rate of flow in dry cold weather than in warm weather.

22775 *Mr. Fowler* (*Manchester*): Experiments indicate that about half the organic suspended matter disappears in the septic tanks in Manchester. (Evidence, however, not as thorough as is desirable.) Judging by the rate of evolution of gas, digestion is more rapid in warm weather.

22923 Possibly, though not certain, about 25 per cent. of the total suspended matter is liquefied or converted into gas.

(*See also* 5543–5 and 8363–75, Interim Report, Vol. II.).

23611 *Mr. Haworth* (*Sheffield*): An experiment at Sheffield indicated a digestion of 32·9 per cent of sludge. (Scum was thicker in winter than in summer.)

23670-5 Experiment as regards digestion lasted seventeen months, and samples were taken daily. The digestion of 32·9 per cent. is the proportion of the total suspended matter in sewage, not the digestion of the sludge in tank.

24985 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): Figures available indicate that digestion does not exceed 10 per cent. of suspended matter entering tanks. Digestion much more vigorous in summer than in winter.

25300-1 There was some digestion in the long conduit and in the Dortmund tanks before sewage reached septic tanks.

(29.) What is the Amount of Digestion in a Septic Tank. How far is this Affected by the Atmospheric Temperature (*continued*). SEPTIC TANKS

26056 *Messrs. Willcox & Raikes*: At Hanley about half the suspended matter is digested or liquefied. There was greater digestion at other places where tanks had been used for several years without requiring cleaning out (26170). Septic action is sometimes temporarily increased by rise of temperature.

26991 *Mr. F. W. Stoddart*: Experiments at Knowle showed that sludge left in tank diminished from 32 inches to 19 inches in depth in three months in one case, and from 44 inches to 13 inches in twelve months in another case. Results, however, did not encourage the idea that the whole of the sludge could be destroyed by leaving it in the tank.

SEPTIC TANKS.

(30.) SHOULD A CERTAIN AMOUNT OF SLUDGE BE REMOVED PERIODICALLY FROM SEPTIC TANKS, OR SHOULD THEY BE WORKED FOR A CONSIDERABLE PERIOD WITHOUT CLEANING AND THEN ALL THE SLUDGE REMOVED.

Interim Report : Vol. II. (Cd. 686), 1902.

1902 *Mr. D. Cameron (Exeter):* Seems to think it important that tank should not be emptied entirely of sludge. Has suggested a means of taking away small quantities periodically.

7252 *Col. Harding:* Much better to remove at intervals some of the deposit through a valve. This can generally be done in small tanks. Sludge might be removed from large tanks, say, once a year, but care should be taken to leave a certain quantity behind to maintain septic conditions.

Fifth Report : Appendix I.

20751 *Messrs. Raymond Ross & Pickles (Burnley)*: Prefer to remove it entirely at fairly long intervals, as the greater part accumulates at surface of tanks.

At Burnley septic tanks are entirely cleaned every six months.

20913-7 If practicable, it would be advantageous to remove a portion of the sludge at frequent intervals and keep tanks at a constant capacity.

21124 *Mr. Bolton (Heywood)*: Finds it best to let the tank run a fair length of time and then remove all the sludge. Removal of portions of sludge at short intervals disturbs the tanks, and it is necessary to allow time for settling. Agrees, however, that, if practicable, it would be desirable to remove a portion of the sludge frequently so as to keep tanks at a constant capacity (21335–9.)

21634 *Mr. Campbell (Huddersfield)*: Sludge should accumulate until there is marked increase in suspended matter in effluent. The bulk of the sludge, but not the whole of it, should then be removed. Agrees, however, that it would be preferable to remove small portion of sludge frequently, and that this would be quite practicable from engineering point of view (21812–25).

21995 *Mr. Harrison (Leeds)*: A certain amount of sludge ought to be removed at regular intervals.

22629 *Dr. Wilkinson (Oldham)*:
22437 *Mr. Valentine (Oldham)*: } In favour of drawing off the sludge from time to time while the tank is working.

(30.) SHOULD A CERTAIN AMOUNT OF SLUDGE BE REMOVED PERIODICALLY FROM SEPTIC TANKS, OR SHOULD THEY BE WORKED FOR A CONSIDERABLE PERIOD WITHOUT CLEANING AND THEN ALL THE SLUDGE REMOVED (*continued*). SEPTIC TANKS.

23776 23085 *Mr. Fowler* (*Manchester*) : Undoubtedly better to remove a certain amount periodically, say, once a month.

23087 Describes method adopted at Manchester for removing sludge periodically

23544 *Mr. Wike* (*Sheffield*) : Tanks may be worked for long periods without sludging, but sludge should not be allowed to accumulate until it rises in the tank and is carried out with the effluent.

24268 *Mr. Wilkinson Manchester*) : There should be periodical removal of portion of sludge. In no case should accumulation exceed 20 or 25 per cent. of depth of tank.

24408 Quite practicable to remove portion of sludge at intervals.

24432 (p. 575) *Dr. Reid* : Tanks should be worked as long as possible without removing the sludge.

24986 *Messrs. Watson & O'Shaughnessy* (*Birmingham*) : There should be periodical removal of portion of sludge. This is quite practicable (25309–10).

25312-5 Essential that tank should not be wholly emptied of sludge.

26057 *Messrs. Willcox & Raikes* : Tanks should be emptied and cleaned out when suspended matter in effluent exceeds from 5 to 8 parts per 100,000, though their action should never be interfered with or disturbed when this can be avoided.

26991 *Mr. F. W. Stoddart* : During some experiments at Knowle it was found desirable to remove part of the sludge at intervals rather than to let it accumulate in the tank.

TANKS

(31.) HOW SHOULD SLUDGE BE TAKEN OUT OF A SEPTIC TANK: DOES ANY NUISANCE ATTEND THE OPERATION.

Interim Report: Vol. II. (Cd. 686), 1902.

2051 *Mr. D. Cameron (Exeter)*: Septic tank sludge unless warmed and stirred is practically inodorous, and he anticipates no nuisance in removing it.

7253
7286–8
7252 *Col. Harding:* No doubt septic tank sludge will at the time be more offensive than chemical precipitation, but the nuisance would probably soon be over, because the putrefaction would be sooner completed. Sludge from septic tanks at Leeds not found very offensive. Removal should be by means of a valve in the bottom of the tanks—in case of small tanks at any rate. May be necessary in large tanks to run off supernatant liquor, and then remove sludge in usual way. Septic tank sludge easier to deal with, as it settles and dries more rapidly.

Fifth Report: Appendix I.

20753 *Messrs. Raymond Ross & Pickles (Burnley)*: At Burnley supernatant liquid is run off, sewage is then run on to the settled sludge and the sludge then pumped to an empty tank where lime is added. No difficulty in pressing septic sludge when lime is mixed with it.

There is no nuisance (21008–9)

21126 *Mr. Bolton (Heywood)*: By drawing off as much water as possible, and then passing the sludge through a pipe at the bottom of the tank. Very offensive smell during sludging.

21636 *Mr. Campbell (Huddersfield)*: Should be run out by means of valve at bottom of tank, and then pressed and burned or deposited in lagoons. No nuisance.

22630 *Dr. Wilkinson (Oldham)*: There is great difficulty in pressing the sludge from septic tanks. At Oldham it is allowed to solidify in storage tanks and to dry naturally.

22777 *Mr. Fowler (Manchester)*:
24269 *Mr. Wilkinson*: Should be forced out of tank automatically by the pressure of the water. Hand labour should be avoided as far as possible: there is risk of nuisance and also risk of explosions if naked lights are used.

(31.) How should Sludge be taken out of a Septic Tank: Does any Nuisance attend the Operation (*continued*). SEPTIC TANKS.

23545 *Mr. Wike* (*Sheffield*) : Septic tank sludge is more objectionable than sludge from settling tanks, and the work of removal is offensive.

24432 (p. 575) *Dr. Reid*: A portable pump would be sufficient. No nuisance from septic tank sludge.

4988 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): Should be removed in fluid form, and without running off the liquid contents overlying sludge. No nuisance need attend the operation. (But see 24987 and 25108–25115, where it is suggested that liquid should be run off and sludge left in tank for two or three days before removal.)

26059 *Messrs. Willcox & Raikes*: Sludge can be removed by gravitation and can be buried or pressed without nuisance.

SEPTIC TANKS

(32.) DO THE SUSPENDED SOLIDS COMING AWAY WITH THE SEPTIC TANK LIQUORS TEND TO INCREASE AS THE TIME APPROACHES FOR REMOVING SLUDGE FROM THE TANK.

Fifth Report : Appendix I.

20754 *Messrs. Raymond Ross & Pickles (Burnley)* : Yes.

21127 *Mr. Bolton (Heywood)* : Yes.

21637 *Mr. Campbell (Huddersfield)* : Yes.

21997 *Mr. Harrison (Leeds)* : Yes, undoubtedly.
(*See also* 7250, Interim Report : *Col. Harding.*)

22439 *Mr. Valentine (Oldham)* : Yes.

22631 *Dr. Wilkinson (Oldham)* : Yes, considerably.

22778 *Mr. Fowler (Manchester)* : Yes.

23546 *Mr. Wike (Sheffield)* : Yes.

23[illegible]12 *Mr. Haworth (Sheffield)* : Yes ; solids begin to increase after three or four weeks' work.

(32.) Do the Suspended Solids coming away with the Septic Tank Liquors tend to Increase as the Time approaches for Removing Sludge from the Tank (*continued.*)

24270 *Mr. Wilkinson* (*Manchester*): Yes.

24989 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): There is a tendency for solids to increase as tanks silt up. To keep conditions constant, there should be preliminary tanks for the sewage to pass through before it reaches the septic tanks (25051).

26060 *Messrs. Willcox & Raikes*: Yes.

26991 *Mr. F. W. Stoddart*: Yes.

SEPTIC TANKS.

(33.) WHAT AMOUNTS OF SUSPENDED SOLIDS ARE CONTAINED IN THE SEPTIC TANK LIQUOR AT THE COMMENCEMENT OF THE PERIOD OF WORKING THE TANK AND AT THE END OF THE PERIOD, AND WHAT IS THE AVERAGE AMOUNT.

Fifth Report: Appendix I.

20755 *Messrs. Raymond Ross & Pickles (Burnley)*: With ten tanks (capacity about ten hours' dry-weather flow) the suspended matter varied from 15 parts per 100,000 after a few weeks working to 35 parts per 100,000 at end of six months.

21128 *Mr. Bolton (Heywood)*: From samples he obtained elsewhere, where tank was dealing with weak sewage, he got the following figures:—

Just after starting, amount of suspended solids	3 parts per 100,000
After six months, ,, ,, ,,	9 ,, ,,

21638 *Mr. Campbell (Huddersfield)*: Eleven months' trial gave:—

At commencement	6·6 parts per 100,000
At end	23·3 ,, ,,
Average during period	13·2 ,, ,,

21998 *Mr. Harrison (Leeds)*: From January to June 1903, with a perfectly clean tank, the suspended solids averaged 12·2 parts per 100,000: from July to December, 1904, the average from same tank was 24·1 parts.

22779 *Mr. Fowler (Manchester)*: Typical figures are:

	Organic and Volatile.	Mineral.	Total.
Average for 1st month	2·0	1·0	3·0
Average for next two months	3·1	2·3	5·4
,, ,, 2 ,,	4·1	3·1	7·2

23613 *Mr. Haworth (Sheffield)*:

8 to 11 parts per 100,000 in early stages.
17 to 18 ,, ,, after several months' work.
(very variable in later stages.

(33.) What Amounts of Suspended Solids are contained in the Septic Tank Liquor at the Commencement of the Period of Working the Tank and at the End of the Period, and what is the Average Amount (*continued*).

24990 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): Average amount for 1903 was 19·5 parts per 100,000 At the end of the year, just after the tanks were cleaned out, the solids in the effluent fell to 4 parts per 100,000.

26061 *Messrs. Willcox & Raikes*: At Hanley, septic tanks become efficient after about three weeks' working when effluent contains about 5 parts per 100,000 suspended matter. This is not appreciably increased after twelve months' working.

26991 *Mr. F. W. Stoddart*: At Knowle, suspended solids in tank effluent varied from 8 to 20 parts per 100,000 and averaged 14 parts per 100,000.

SEPTIC TANKS.

(34.) SHOULD ANY PORTION, OR THE WHOLE, OF THE SEWAGE WHICH ARRIVES AT THE OUTFALL IN STORM TIMES BE PASSED THROUGH THE SEPTIC TANKS.

Interim Report: Vol. II. (Cd. 686), 1902.

1935-6 *Mr. D. Cameron (Exeter)*: Thinks that action in septic tank is not so rapid when the sewage is diluted: found that the gas burns less freely in wet weather than in dry.

2042-6 Has not found the tank exceptionally injuriously affected by increase of flow up to $3\frac{1}{2}$ times the dry-weather flow.

4168 *Dr. Rideal*: The storm water might wash away the colonies of bacteria in the tank. (*See also* 4497.)

4639-40 *Mr. Baldwin Latham*: A sudden flow of storm water through the tank would wash it out.

Fifth Report: Appendix I.

20756 *Messrs. Raymond Ross & Pickles (Burnley)*: Up to three dilutions should pass through the tanks, and after this only until all the polluted storm water has come down.

21129 *Mr. Bolton (Heywood)*: Not advisable to pass storm water through at a greater rate than twice the average dry-weather rate.

21639 *Mr. Campbell (Huddersfield)*: Not advisable to pass any portion of the storm water through septic tanks. Ascertained by analyses that tanks do not work so satisfactorily when storm water is admitted (21736).

21972 *Mr. Harrison (Leeds)*: No answer to this specific question. (But see reply to general question as to treatment of storm waters: Question No. 4, page 16.)

22440 *Mr. Valentine (Oldham)*: Is in favour of sending the first portion of storm sewage through the tanks, and subsequently limiting the flow through them to not more than twice or thrice the normal flow.

(34.) SHOULD ANY PORTION OR THE WHOLE OF THE SEWAGE WHICH ARRIVES AT THE OUTFALL IN STORM TIMES BE PASSED THROUGH THE SEPTIC TANKS (*continued*).

22632 *Dr. Wilkinson* (*Oldham*): The first portion must be treated. If not in too great quantity and too long continued, it appears to cause no great harm to the septic tanks.

22780 *Mr. Fowler* (*Manchester*): A portion only, not more than a 2 to 1 dilution.

23547 *Mr. Wike* (*Sheffield*): Septic tank not suitable for storm water sewage.

24272 *Mr. Wilkinson* (*Manchester*): Not more than double the dry-weather flow should be allowed to pass through.

24991 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): Generally speaking, no. Have had tanks spoiled by the running of storm water through them (25116–7).

26062 *Messrs. Willcox & Raikes*: Any material increase of rate of flow during storms is detrimental to septic action.

SEPTIC TANKS.

(35.) IF STORM SEWAGE IS PASSED THROUGH A SEPTIC TANK, DOES THIS CAUSE AN INCREASE IN THE AMOUNT OF SUSPENDED SOLIDS ISSUING FROM THE TANK.

Interim Report: Vol II. (*Cd.* 686), 1902.

7351-2 *Col. Harding:* Unless tank is of sufficient size to cope with increased flow (say 48 hours' capacity, if six dilutions are admitted), there will be increase of suspended solids in effluent.

Fifth Report: Appendix I.

20757 *Messrs. Raymond Ross & Pickles* (*Burnley*): Storm of four hours' duration (1 a.m. to 5 a.m.). Suspended solids :—

1st hour	4·0 parts per 100,000
2nd „	8·0 „ „
3rd „	8·0 „ „
4th „	9·6 „ „

(*See also* 20968–71.)

21130 *Mr. Bolton* (*Heywood*): Yes, a considerable increase when it is passed through at the rate of three times dry-weather flow. The suspended solids have increased up to thirty-eight parts per 100,000 in storm times.

21640 *Mr. Campbell* (*Huddersfield*): Believes solids will remain in the tank under a certain rate of flow. (Rate not stated.)

22441 *Mr. Valentine* (*Oldham*): This depends greatly on the amount of suspended matter in the sewage and the amount of sludge in the tanks. Where there is not much sludge in the tank, the rate of flow can be increased up to twice or thrice the normal rate without causing any appreciable difference in the amount of suspended solids in the tank liquor.

22781 *Mr. Fowler* (*Manchester*): The amount of suspended solids is increased largely in the early stage of the flow: afterwards the effluent contains less than usual. No exact figures.

25384 *Mr. Wike* (*Sheffield*): Yes, if rate of flow is increased.

(35.) If Storm Sewage is passed through a Septic Tank, does this cause an Increase in the Amount of Suspended Solids issuing from the Tank (*continued.*) **SEPTIC TANKS.**

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273 *Mr. Wilkinson* (*Manchester*): Would suppose so; but has no exact data.

992 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): Yes: very considerable increase.

063 *Messrs. Willcox & Raikes*: Yes.

SEPTIC TANKS.

(36.) CAN THE ORDINARY LEVEL OF THE LIQUID IN A SEPTIC TANK BE ALTERED (BY THE ADMISSION OF STORM SEWAGE OR OTHERWISE) WITHOUT SERIOUS DETRIMENT TO THE FUNCTIONS OF THE TANK.

Fifth Report: Appendix I.

21641 *Mr. Campbell (Huddersfield)*: It would impair septic action for a time. Ascertained this by analyses of septic tank liquor in times of storm (21736).

21999 *Mr. Harrison (Leeds)*: Yes: the closed tank at Leeds is operated upon the principle of a fluctuating water level.

22781 *Mr. Fowler (Manchester)*: Thinks so, within limits; knows of cases where this is done with the object of obtaining a head and a measured quantum of liquid for discharging on to a filter.

24993 *Messrs. Watson & O'Shaughnessy (Birmingham)*: Only to a limited extent.

26064 *Messrs. Willcox & Raikes*: No experience, but if rate of flow is maintained uniform no harm is likely to result.

(37.) IS SEPTIC TANK LIQUOR MORE EASILY TREATED ON FILTERS THAN SETTLED SEWAGE OR THAN PRECIPITATED SEWAGE, ASSUMING THAT IN EACH CASE THE TANK LIQUOR CONTAINS THE SAME AMOUNT OF SUSPENDED SOLIDS.

Interim Report: Vol II. (Cd. 683), 1902.

7262 *Col. Harding:* Filtration is only assisted by septic tank treatment by reason of the disintegration of the gross suspended solids.

Fifth Report: Appendix I

20760 *Messrs. Raymond Ross & Pickles (Burnley)*: Obtained better results with septic tank liquor than with chemically precipitated sewage.

21132 *Mr. Bolton (Heywood)*: Septic tank liquor is not more easily treated than precipitated sewage at Heywood. Filters treating precipitated sewage give an average of 64 per cent. purification, while filters treating septic tank liquor gave only 53 per cent. The suspended solids in the septic tank liquor appeared to be more abundant.

21643 *Mr. Campbell (Huddersfield)*: Septic tanks would prepare the sewage better for the beds than either precipitation or settlement, if the sewage is not acid or strongly antiseptic. Speaks from actual experience and observation (21737).

22000 *Mr. Harrison (Leeds)*: Has not found that septic tank liquor is more easily treated on filters. Has made comparative observations.

Is of opinion that all three liquors, if amount of suspended solids is approximately the same, give identical results with the same method of filtration.

22442 *Mr. Valentine (Oldham)*: A septic treated sewage is the one that can be most efficiently treated on filters; the advantages from septic tank treatment are—

(*a*) A more equable tank effluent.

(*b*) The effluent is in a better condition for subsequent filtration; *i.e.*, the organic impurities are in a simpler condition than in settled sewage. (The above view founded chiefly on observations at Manchester: 22518.)

(*c*) There is a certain amount of digestion of solids. (Ascertained by actual experiment: 22520-2.)

SEPTIC TANKS.

(37.) Is Septic Tank Liquor more easily treated on Filters than Settled Sewage or than Precipitated Sewage, assuming that in each case the Tank Liquor contains the same Amount of Suspended Solids (*continued*).

22636 *Dr. Wilkinson* (*Oldham*): A better effluent is obtained with a septic tank liquor, and the filtrate seldom undergoes putrefaction when incubated. A filtrate from a septic tank liquor of the same standard as that from a sedimentation tank liquor is much less likely to again undergo putrefaction. (Results of numerous analyses by Mr. Valentine and his predecessor: 22700–1.)

32757 *Mr. Fowler* (*Manchester*): Is inclined to think so from the results at Manchester. No exact comparative experiments were made (*see* No. 17, page 36.)

From earlier observations of the filtration of septic tank liquor, settled sewage, and crude sewage, he was strongly of opinion that the septic tank treatment rendered the sewage easier to deal with by filtration, 8408–13. (Interim Report.)

23550 *Mr. Wike* (*Sheffield*): Septic tank liquor is more suitable for treatment on contact beds than chemically precipitated sewage, but not more suitable than settled sewage.

23640 *Mr. Haworth* (*Sheffield*): Agrees with Mr. Wike. Limed sewage at Sheffield appears to sterilise contact beds; it contains from five to seven grains per gallon of free lime.

24432 (p. 575) *Dr. Reid*: In practice, chemically precipitated sewage is more readily dealt with by filtration than either settled sewage or septic tank liquor because of its comparative freedom from suspended solids.

(38.) ARE THE IMPURITIES IN SOLUTION IN SEWAGE MATERIALLY DIFFERENT FROM THE IMPURITIES IN SOLUTION IN SEPTIC TANK LIQUOR.

Fifth Report: Appendix I.

21644 *Mr. Campbell (Huddersfield)*: Yes: complex bodies in sewage are reduced, there being a very much smaller albuminoid ammonia and a smaller oxygen absorbed than in settled sewage, while free ammonia is higher.

22443 *Mr. Valentine (Oldham)*: Has found that a septic tank effluent contains three to four parts in 100,000 excess in solution over a settled sewage effluent.

22775 (p. 370) *Mr. Fowler (Manchester)*: Researches at Manchester suggest a breaking down of albuminoid and cellulose matter in the septic tank into simpler and to some extent volatile compounds. The re-actions are probably hydrolytic in character, ammonia, amines, carbonic acid, water, and possibly alcohol being produced. A further quantity of organic matter also disappears as methane, nitrogen and hydrogen.

24432 (p. 575) *Dr. Reid*: Thinks that there is material reduction in oxidisable organic matter in solution.

24966 *Messrs. Watson & O'Shaughnessy (Birmingham)*: Speaking broadly, no; but the proportions between the relative quantities of the different constituents are considerably modified by the septic process.

26091 *Mr. F. W. Stoddart*: Has found that if putrefaction is carried too far in a septic tank, secondary deposits are caused which are not present in the original sewage at all, prominent amongst them being a gelatinous ferrous sulphide.

(39.) WHAT IS THE RELATIVE VALUE OF PLAIN SEPTIC TANKS AND SEPTIC TANKS FILLED WITH ROUGH STONES OR FLINTS.

Interim Report: Vol. II. (Cd. 686), 1902.

2945 *Dr. Sims Woodhead:* Suggests that stones form a larger surface on which the organisms grow, and that there would not be so many of these organisms washed away in the event of a storm or flood as there would be in the case of ordinary septic tanks.

3394 *Mr. Scott Moncrieff:* Thinks that the provision of stones makes it possible to reduce considerably the capacity of the tank in relation to the dry-weather flow.

4139 *Dr. Rideal:* The system by which successive zones or habitats are established so that sewage passing through is exposed to a natural cycle of change is carried further in the Scott Moncrieff tank than in the ordinary septic tank. The stones become coated with zooglœa layers of different organisms at successive points.

Fifth Report: Appendix I.

24432 (p. 575) *Dr. Reid:* Has not sufficient data to express positive opinion; but is strongly inclined to the opinion from his experience that tanks filled with stones or flints possess no advantage.

24997 *Messrs. Watson & O'Shaughnessy (Birmingham):* No appreciable difference in effluent.

26068 *Messrs. Willcox & Raikes:* Effective capacity of tank equals amount of water it can hold, and this is reduced in proportion to bulk of any other materials placed in it.

(40.) IS THERE ANY NUISANCE FROM THE TREATMENT OF SEWAGE IN SEPTIC TANKS.

Interim Report: *Vol. II.* (*Cd.* 686), 1902.

2072 *Mr. D. Cameron* (*Exeter*): If sewage is not kept in tank too long, there is very little smell; not enough to be a nuisance. Aerator of septic tank was open for a year within a few yards of public thoroughfare and within 70 yards of large house.

Dr. Sims Woodhead: There is necessarily a certain amount of smell owing to the changes which are going on. Does not think that, either at Exeter or Claybury, the smell was likely to amount to a nuisance.

4957 *Mr. C. J. Whittaker* (*Accrington*): Has no fear of any smell from septic tank, even if very large. Smell from pressed sludge much worse.

6439-45 *Mr. G. Chatterton*: Had experience of undoubted nuisance from open septic tank caused by the scum. (Sewage purely domestic.) Scum had to be removed owing to complaints of neighbours.

6447-8 Does not think there would be nuisance with closed tank. (*See also* 6527–6546.)

6735-6 *Mr. R. A. Tatton*: No nuisance from closed septic tanks dealing with domestic sewage, except at the outflow.

6936 *Mr. W. H. Prescott*: At Reigate, where the sewage is exceptionally strong, containing large quantities of tannery and brewery refuse, a closed septic tank gave a good effluent, but evolved an objectionable smell. Owing to this smell, septic treatment was regarded as inadmissible for the first treatment of Reigate sewage.

7688 *Mr. G. R. Strachan*: Has found that all effluents from septic tanks in which putrescence has occurred have smelt.

8169-82 *Mr. E. G. Mawbey*: Experiment at Leicester, lasting four and a half months, showed that septic tank effluent could not be treated on land without causing a nuisance. (Probably due to anærobic conditions being carried too far: 8222.)

(40.) IS THERE ANY NUISANCE FROM THE TREATMENT OF SEWAGE IN SEPTIC TANKS (*continued.*)

9975 *Dr. P. F. Frankland*: There is necessarily a smell, but it is very trifling. (Refers to experience of the large tank at Manchester.)

Fourth Report: Vol. II. (Cd. 1884), 1904.

18748 *Dr. Clowes*: His experience of small installations shows that if sewage remains in tank much longer than twenty-four hours a nuisance results.

Fifth Report: Appendix I.

20763 *Messrs. Raymond Ross & Pickles (Burnley)*: No.

21135 *Mr. Bolton (Heywood)*: A very offensive smell is given off. More particularly from the liquid passing out of the tank (21213).

21645* *Mr. Campbell (Huddersfield)*: No.

22001 *Mr. Harrison (Leeds)*: Very little, if any, nuisance arises from the open tanks at Leeds; this is probably due to presence of iron in the sewage.

22445 *Mr. Valentine (Oldham)*: No.

22639 *Dr. Wilkinson (Oldham)*: No.

22785 *Mr. Fowler* (*Manchester*): Very little smell from tanks themselves; but trouble arises from the evolution of gas during sludging operations.

Unpleasant odour, too, if atmospheric conditions prevent the gases getting away.

Iron salts present in Manchester sewage prevent evolution of sulphuretted hydrogen.

23552 *Mr. Wike* (*Sheffield*): The working of the experimental tank at Sheffield caused a nuisance.

24432 (p. 575) *Dr. Reid*: Too prolonged septic action intensifies any nuisance which may exist, and the distribution of septic liquor in filters is likely to cause nuisance.

24998 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): No.

26069 *Messrs. Willcox & Raikes*: No.

26991 *Mr. F. W. Stoddart*: Where the sewage remains for too prolonged a period in the tank (twenty-four hours
27025 or more) secondary products are formed which give a very offensive odour to the ordinary septic tank effluent.

TANKS IN GENERAL

(41.) IS IT DESIRABLE THAT THE SUSPENDED SOLIDS IN SEWAGE SHOULD BE REMOVED AS FAR AS PRACTICABLE BEFORE SEWAGE IS FILTERED. WHAT IS A PRACTICABLE STANDARD.

Interim Report: Vol. II. (Cd. 686), 1902.

1673 *Mr. Santo Crimp:* Yes.

page 129 *Mr. W. J. Dibdin:* Preliminary treatment desirable, and essential in many cases.

2930 *Dr. Sims Woodhead:* Thinks that no precipitation is necessary in case of ordinary sewage.

3180-3 *Mr. Scott Moncrieff:* Grease presents difficulties of a special character and must be arrested.

3694 *Sir H. Roscoe:* Has no evidence that artificial filtration can be carried out successfully without previous subsidence or chemical treatment.

5019 *Mr. F. W. Stoddart:* It is not profitable to throw any material amount of solid matter on any kind of filter.

7396 *Colonel Harding:* Given satisfactory removal of grosser suspended solids and fibre, thinks it quite practicable to deal with Leeds sewage on trickling filters without antecedent septic treatment.

7518 *Mr. G. R. Strachan:* Yes, preliminary treatment is useful and advisable; but does not say that it is essential.

Fifth Report: Appendix I.

20764 *Messrs. Raymond Ross & Pickles (Burnley):* Yes, as far as possible. At Burnley, they get down to 5–6 parts per 100,000; the installation includes large detritus tanks which are frequently emptied, not being allowed to become septic; and the sewage is taken from the septic tanks in a very thin film (*See* 20890–902).

(41.) Is it Desirable that the Suspended Solids in Sewage should be Removed as far as practicable before Sewage is Filtered. What is a Practicable Standard (*continued*). TANKS IN GENERAL

21136 *Mr. Bolton* (*Heywood*): Essential that solids should be removed as far as possible. Practicable limits 4 parts per 100,000 for chemically treated sewage, 8 parts per 100,000 for septic tank liquor.

21456 *Mr. Kershaw* (*Rotherham*): Yes, as much as possible.

21646 *Mr. Campbell* (*Huddersfield*): Yes, most desirable, 6 to 8 parts per 100,000 is a practicable limit. (Reaffirmed in 21739–42.) Tanks are cleaned out four times a year.

22003 *Mr. Harrison* (Leeds): Yes, the difficulty of treating any liquid effectively is proportionate to the amount of suspended solids it contains.

With septic tanks, even with seventy-two hours' flow, it is impossible at Leeds to reduce suspended solids below an average of 14 parts per 100,000; by chemical precipitation reduction to 4·5 to 6 parts can apparently be obtained.

22446 *Mr. Valentine* (*Oldham*): Yes, to a limit of about 10 or 11 parts per 100,000.

22640 *Dr. Wilkinson* (*Oldham*): Yes.

22786 *Mr. Fowler* (*Manchester*): Unless the filter is specially constructed to deal with suspended solids, it is probably economical to keep the greater proportion off the beds. The economical limit is about 11 parts per 100,000.

23093 In some cases, it may be desirable that the whole or the greater part of the suspended solids should be dealt with by filtration.

23223 *Mr. Carter Bell* (*Salford*): Yes, 1·5 parts per 100,000 is a practicable limit (*i.e.*, by chemical precipitation).

(41.) Is it Desirable that the Suspended Solids in Sewage should be Removed as far as practicable before Sewage is Filtered. What is a Practicable Standard (*continued*).

23553 *Mr. Wike* (*Sheffield*): Yes.

23614 *Mr. Haworth* (*Sheffield*): Yes, to 8 to 10 parts per 100,000 by suitable tank treatment.

24278 *Mr. Wilkinson* (*Manchester*): Yes, to not more than 6 parts per 100,000, if possible.

24432 (p. 575) *Dr. Reid*: Yes. A practicable limit for a septic tank liquor is from 5 to 8 parts per 100,000, and for a chemically precipitated effluent, 2 to 3 parts.

24688 *Dr. Letts*: Yes.

24999 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): Yes, practicable limit is about 8 parts per 100,000.

25830 *Mr. F. Scudder*: By simple subsidence, suspended matters can be reduced to 3 or 4 grains per gallon.

26070 *Messrs. Willcox & Raikes*: Yes, suspended matters in liquid passed on to filters should not exceed about 5 parts per 100,000

(42.) HOW CAN THE REMOVAL OF SUSPENDED SOLIDS BEST BE EFFECTED.

Interim Report: Vol. II. (Cd. 685), 1902.

74 *Mr. Santo Crimp*: In favour of natural deposition. Has used largely, with excellent results, a tank containing a bed of gravel through which the sewage flows upwards. This removes mineral matter and floating organic matters.

20 *Mr. G. R. Strachan*: Would prefer large tanks holding a day or a day and a half flow of sewage. (Guided by bacteriologists and his own observations as an engineer.)

Fifth Report: Appendix I.

765 *Messrs. Raymond Ross & Pickles (Burnley)*: In three stages—firstly, by screening; secondly, large detritus tanks; thirdly, septic tanks of at least twenty-four hours' dry-weather flow capacity.

137 *Mr. Bolton (Heywood)*: A well constructed tank with suitable inlets and outlets.

457 *Mr. Kershaw (Rotherham)*: Tank accommodation should be ample: the flow through them should be steady: the sludge should be removed at frequent intervals.

647 *Mr. Campbell (Huddersfield)*: Chemically precipitated effluents are most free from suspended solids. If, however, a portion of the sludge near the outlet could frequently be removed, equally good results might be obtained with a septic tank.

004 *Mr. Harrison (Leeds)*: To remove the solids as far as possible, precipitation with an efficient settlement area is required. In some cases, sedimentation without chemicals would suffice.

447 *Mr. Valentine (Oldham)*: By a system of septic tanks in series. Has no practical experience of tanks in series, however.

TANKS IN GENERAL

(42.) HOW CAN THE REMOVAL OF SUSPENDED SOLIDS BEST BE EFFECTED (*continued*).

22787 *Mr. Fowler (Manchester)*: Thorough chemical precipitation is most effective, but is costly. Small doses of chemicals do not effect much more than simple sedimentation or septic tank treatment. Important in each case, that the tank be designed carefully to effect the greatest settlement in a small space, and that the sludge be not allowed to accumulate beyond a certain critical depth.

23224 *Mr. Carter Bell (Salford)*: By raising sewage through roughing filters of 3 feet in depth of gravel. (These quickly choke up and have to be cleared every two or three months, 23324–6). Filters remove about 50 per cent. of suspended matter from tank effluent, 23447–9.

23554 *Mr. Wike (Sheffield)*: By catch-pits and settling tanks.

24279 *Mr. Wilkinson (Manchester)*: By passing liquor through a streaming filter after tank treatment.

24432 (p. 575) *Dr. Reid*: Undoubtedly best way is by chemical precipitation. But there is the difficulty of sludge disposal and the question of cost. No need to use chemicals under ordinary circumstances. Septic tank sufficient.

With proper detritus tank preceding it, septic tank will reduce suspended solids to 5 to 8 parts per 100,000.

25000 *Messrs. Watson & O'Shaughnessy (Birmingham)*: By simple sedimentation.

25831 *Mr. F. Scudder*: Either by chemical precipitation or subsidence.

26071 *Messrs. Willcox & Raikes*: By small detritus tanks followed by liquefying tanks.

(43.) WHAT METHODS ARE THERE FOR FREEING TANK LIQUOR OF SUSPENDED MATTER BEFORE IT IS DELIVERED TO FILTERS.

Fifth Report: Appendix I.

21138 *Mr. Bolton (Heywood):* Solids could be reduced very considerably by a mechanical filter or centrifugal action in tanks. The first method is costly and there is loss of head in the second.

21459 *Mr. Kershaw (Rotherham):* With ample tank accommodation, no further treatment of effluent before it is passed into filters is necessary.

21649 *Mr. Campbell (Huddersfield):* None necessary.

22788 *Mr. Fowler (Manchester):* Mechanical strainers and like devices are not very successful. Has found that the greater part of the visible suspended matter can be removed by covering a portion of the surface of the filter (contact bed) with a thin layer of fine material, either small clinker or gravelly sand.

23225 *Mr. Carter Bell (Salford):* Has for many years used roughing filters of graded gravel and coarse sand These can remove about 75 per cent.

5001 *Messrs. Watson & O'Shaughnessy (Birmingham):* Dortmund tanks very efficient. Not necessary or desirable to adopt any other method.

26072 *Messrs. Willcox & Raikes:* Tank liquor sometimes strained through fine sand in mechanical filters, but a properly designed tank usually gives a good enough effluent without such straining.

TANKS IN GENERAL

(44.) WHAT ARE THE COMPARATIVE COST AND RELATIVE ADVANTAGES OF THE VARIOUS METHODS OF SETTLEMENT.

Interim Report : Vol. II. (Cd. 686), 90.

2156-60 *Mr. D. Cameron (Exeter) :* Septic tank will do the work equal to the best form of chemical precipitation. It has the economical advantage that there is not the sludge to be dealt with : and further, the septic tank effluent will not again set up putrefactive changes, whereas there is risk of the chemically treated effluent setting up after-fermentation.

6453 *Mr. G. Chatterton :* Septic tank treatment, he believes, is both cheaper and more efficacious than chemical precipitation (no figures).

7261 *Col. Harding :* Advantages of septic tanks :—

(*a*) Equalises sewage and gives fairly constant conditions for filtration.

(*b*) Digests some of the suspended solids.

(*c*) Suspended solids in effluent in a finely divided condition and less likely to choke filters.

(*d*) There is no loss of head,

(*e*) Saves cost of chemicals, and sludge production is reduced by nearly half (compared with chemical precipitation).

(*d*) Drying of septic tank sludge on land or in lagoons involves less risk of nuisance than is the case with sludge from chemical precipitation tanks.

Advantage of chemical precipitation is the more thorough withdrawal of suspended solids ; the less suspended solids the easier the filtration.

Fifth Report : Appendix I.

20768 *Messrs. Raymond Ross & Pickles (Burnley) :*

	Comparative Cost at Burnley.	
	Chemical Precipitation.	Septic Tanks.
Initial outlay	(About the same for both.)	
	£ s. d.	£ s. d.
Annual expenses, less receipts from manure	1,613 10 4	980 19 9
Cost of treatment per 1,000,000 gallons of dry-weather flow	2 4 2	1 6 8

Twice the amount of sludge was produced by chemical precipitation.

Chemical precipitated effluent did not give such satisfactory results on filtration as septic tank liquor.

(44.) What are the Comparative Cost and Relative Advantages of the Various Methods of Settlement (*continued*).

21140 *Mr. Bolton* (*Heywood*): Had experience only of quiescent and continuous flow, with chemicals, and septic tank treatment. Unable to make comparison on basis of same figure for suspended solids.

(*a*) *Settlement*, with chemicals.

Advantage of quiescent flow: Slightly better result on the average than by continuous flow

Disadvantages: More attention and consequently extra labour required than by continuous flow. Effluent not uniform as in the case of continuous flow.

Cost of subsequent filtering about equal.

(*b*) *Septic tank.*

Advantages: Considerable saving in chemicals. (At Heywood £353 per annum.) Saving of nearly half the cost of sludge pressing.

Disadvantages: Purification only 36 per cent. against 62 per cent. by chemical precipitation. Double contact required against single contact for precipitated liquor. Risk of nuisance greater.

Comparative annual cost at Heywood:—Continuous flow settlement, with chemicals, £2,801; quiescent settlement, with chemicals, £2,835; septic tanks, £2,255.

(Cost is calculated on the basis of equal efficiency for all three methods: 21277–81.)

21650 *Mr. Campbell* (*Huddersfield*):

(*a*) Continuous flow settlement is preferable to quiescent settlement, as it requires little or no attention. On the quiescent plan, the tanks must be run off and filled from time to time.

(*b*) Chemical precipitation is much the quicker, and it is, therefore, a question of initial cost, annual charges, and space.

(*c*) Septic tanks are, on the whole, the best arrangement. The initial outlay is larger, but the annual cost will be very considerably less, having regard to sludge production, subsequent purification, and attention required.

22641 *Dr. Wilkinson* (*Oldham*): He is advising a combination of sedimentation and septic tanks for Oldham the proposal being to run the sewage into a sedimentation tank (continuous flow two to four hours) for settling the heavier solid sludge, and then to pass the partially settled sewage into open septic tanks. In this way, it is anticipated, a weak tank effluent will be obtained, and the septic tanks will be maintained at their greatest capacity.

22790 *Mr. Fowler* (*Manchester*): Exceedingly difficult to say precisely, as circumstances and conditions vary so greatly in different places. The following tabular statement gives in outline certain main considerations affecting the choice of one or other method.

TABULAR STATEMENT HANDED IN BY MR. FOWLER.

——	QUIESCENT SETTLEMENT WITHOUT CHEMICALS. I.	QUIESCENT SETTLEMENT WITH CHEMICALS. II.	CONTINUOUS FLOW SETTLEMENT WITHOUT CHEMICALS. III.	CONTINUOUS FLOW SETTLEMENT WITH CHEMICALS. IV.	SEPTIC TANK TREATMENT. V.
NUISANCE - - - -	In hot weather may rapidly sour and tend to nuisance.	No danger of nuisance.	Tendency to become septic, if not frequently sludged.	No danger of nuisance with reasonable care.	Possible nuisance if uncovered or if flow too small for tank space.
SLUDGE REMOVAL - - -	Likely to obtain liquid and possibly sour sludge.	Large volumes of sludge obtained.	Sludge may be rather more offensive than in IV.	Most dense sludge produced by this method.	Sludge must be removed with precautions as stated in reply to 22777.
PURIFICATION OF TANK LIQUOR - - - -	Large variations in composition of effluents at different times of day, more filter space required than II. or IV. Tendency to septic action increases variability of results.	Some variation in strength of effluent at different times of day, but on the whole requires least filtering area of any method.	More equable effluent than I. or II., but requires more filtering area than either of these.	Same as III., but requires less filtering area.	Most equable effluent with good management can often get well nitrified effluent with single contact.
ANNUAL COST - - -	Cost of pumping out of tanks more than III., IV. or V. unless considerable fall available. Cost saved on chemicals, but more expenditure necessary on filters than in II. or IV.	Cost of pumping out as in I., and large cost in chemicals and sludge, less cost in upkeep of beds.	Less cost than I. and II. in pumping out and in sludge removal and chemicals, more work on beds than II., and possibly than I.	More cost in chemicals and sludge, and less on beds than III.	Less cost in chemicals and sludge than IV. Cost for beds same as III., or possibly more.
INITIAL EXPENDITURE - -	Greater tank area than III. and IV., rather less filter space.	Tank area as in I., but less filter area.	Less tank area than I. and II., more filter area.	Tank area same as III., less filter area than III., more than II.	More tank area than I. to IV., filtering area roughly as in IV.

(44.) What are the Comparative Cost and Relative Advantages of the Various Methods of Settlement (*continued*). TANKS IN GENERAL

23227 *Mr. Carter Bell* (*Salford*): Has tried many experiments, and though various systems sometimes produce identical results, the balance is slightly in favour of continuous flow rather than quiescent settlement. In a given size of tanks, chemical precipitation is much more efficient than simple settlement, either for producing good tank effluent or as a preparation for filter beds. Sludge difficulty has, however, to be borne in mind

23537 *Mr. Wike* (*Sheffield*): Quiescent settlement and continuous flow settlement without chemicals are both cheaper than the septic tank system in arriving at a given result. In neither case would there be difficulty in subsequent purification, nor would there be much difference in annual cost.

Nuisance more likely to arise with septic tanks.

23550 Advantages of settlement over septic tank treatment:—

(1) Tank liquor contains smaller percentage of suspended solids.
(2) Larger volume can be treated with same tank capacity.
(3) Less difficulty in dealing with sludge.
(4) Sludge is much less offensive.
(5) Liquid portion of sewage is frequently made more impure by contact with sludge in septic tank.

23752–9 Has obtained slightly better results with settled sewage than with septic liquor. Parallel experiments carried out.

24281 *Mr. Wilkinson* (*Manchester*):

(*a*) Quiescent settlement without chemicals generally more advantageous than continuous method. An important advantage in quiescent method is that the discharge may easily be arranged to be automatic. The quiescent system with automatic arrangements for filling and discharging affords the best and most accurate method of separating a defined quantity for treatment in tanks and filters. The great disadvantage of quiescent system is loss of fall involved.

(*b*) Quiescent settlement with chemicals admits of reduction by one-half of period of settlement. Sludge deposited will be greater in volume and containing a larger proportion of water.

(*c*) Continuous flow settlement without chemicals most suitable for storm waters and for weak sewage.

(*d*) Continuous flow with chemicals most widely adopted where chemical precipitation is adopted.

(*e*) Septic tank treatment: advantages are the liquefying and breaking down of portion of organic matters and the reducing of the liquid to a more uniform condition for subsequent filtration.

Comparative Cost.

(Assuming dry-weather flow=1,000,000 gallons, and maximum rate=1,500,000 gallons in 24 hours.)

——	Capital Cost.	Annual Cost.
	£	£
(1) Quiescent settlement without chemicals	1,750	550
(2) ,, ,, with ,,	1,400	800
(3) Continuous flow settlement without chemicals	1,400	550
(4) ,, ,, with ,,	700	900
(5) Septic tanks (covered)*	5,500	300
,, ,, (uncovered)	4,000	300

**i.e.*, covered with a steel girder roof, not a heavy concrete roof, the cost of which would be prohibitive in the case of large tanks (24326–31).

2 346–8 Open septic tank the cheapest *pro rata* with efficiency.

24366–70 Figures given as to comparative cost relate only to settlement, and do not take into account the subsequent dealing with the sewage.

TANKS IN GENERAL

(44.) WHAT ARE THE COMPARATIVE COST AND RELATIVE ADVANTAGES OF THE VARIOUS METHODS OF SETTLEMENT (*continued.*)

24432 (p. 575) *Dr. Reid*: Continuous flow settlement with chemicals, apart from the question of sludge disposal and cost, has advantages over septic tank and primary ærobic filtration.

Primary ærobic filtration has the advantage of freedom from nuisance attending the further treatment of the sewage.

25003 *Messrs. Watson & O'Shaughnessy (Birmingham)*:

(*a*) Annual Cost at Birmingham.

Chemical Precipitation.	*Septic Tank Treatment.*
£	£
7,786	3,280
	676 (loan charges)
	3,956

(*b*) Analytical Results in Parts per 100,000.

	Chemical Precipitation.		Septic Tank Treatment.	
	Dissolved Solids.	Suspended Solids.	Dissolved Solids.	Suspended Solids.
Crude sewage - - - -	129·1	67·6	120·2	60·0
Tank effluent - - - -	138·0	16·3	112·3	21·0
	(Nuisance frequently occurred).		(No nuisance).	

The chemical precipitation method was abandoned in 1901; the figures given are in respect of the last twelve months' working. The figures as to septic tank treatment are for the year ended April 30th, 1905.

25828–31 *Mr. F. Scudder*: Prefers sedimentation or chemical precipitation to septic tank as antecedent treatment to percolating filtration. With sedimentation, the suspended solids can be reduced to 3 or 4 grains per gallon, whereas in septic tank effluents there is invariably a minimum of 8 grains per gallon, which would result in the clogging of the filter eventually.

26074 *Messrs. Willcox and Raikes*: Septic tank treatment is more economical and efficient than settlement with or without chemicals. Settlements without chemicals is inefficient, while settlement with chemicals is more expensive owing to cost of chemicals and increased bulk of sludge.

(45.) SHOULD THE WHOLE OR ANY PART OF THE INTERIOR OF CONTACT BEDS BE CONSTRUCTED OF BUILDING MATERIAL, OR MAY THIS BE DISPENSED WITH ENTIRELY IN SOME CASES. CONTACT BEDS.

Interim Report: Vol. II. (*Cd.* 686), 1902.

Page 127 3808 *Mr. Dibdin:* Bed at Sutton was simply a pit dug in the clay, and filled up with the excavated clay after burning.

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20769 *Messrs. Raymond Ross & Pickles* (*Burnley*): Where soil is heavy, all building material may be dispensed with except for the construction of the outlet chamber.

20868 Have not found that soil works up into filters.'

21141 *Mr. Bolton* (*Heywood*): Where site is unlimited and the foundation is good (*e.g.*, clay), building materials may be dispensed with. All beds should, however, have an impervious bottom to prevent soil being worked up into them.

21218 Has had experience of soil working up into material.

21460 *Mr. Kershaw* (*Rotherham*): With soil of a clay or stiff nature, building material not required except in the construction of valve chamber.

21651 *Mr. Campbell* (*Huddersfield*): Building materials advisable.

22449 *Mr. Valentine* (*Oldham*): Where adjacent beds are on or about the same level, building materials may be dispensed with.

22642 *Dr. Wilkinson* (*Oldham*): Building materials may be dispensed with where the soil allows it and no source of water supply is endangered.

CONTACT BEDS.

(45.) Should the Whole or any Part of the Interior of Contact Beds be Constructed of Building Material, or may this be dispensed with entirely in some Cases (*continued.*)

22791 *Mr. Fowler* (*Manchester*): Where there is a good clay or other suitable subsoil, concrete can be dispensed with.

23558 *Mr. Wike* (*Sheffield*): The necessity for building materials depends upon the circumstances, *e.g.*, nature of soil, whether any source of water supply is affected, area and price of land, etc.

24282 *Mr. Wilkinson* (*Manchester*): As a rule, beds should be made of building materials, both walls and flooring.

24681 *Dr. Letts*: Any construction which makes interior watertight and stable is suitable

26075 *Messrs. Willcox & Raikes*: All contact beds should be watertight, and this almost always necessitates masonry walls and floors. A smooth concrete floor is practically essential for facilitating proper drainage and æration.

(46.) MAY THE DEPTH OF CONTACT BEDS VARY WITHIN CERTAIN LIMITS: WHAT LIMITS ARE PERMISSIBLE.

CONTACT BEDS.

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1693 *Mr. Santo Crimp*: Thinks 3 feet the best depth for artificial filters

2052 *Mr. D. Cameron* (*Exeter*): Thinks beds should be not more than 4 feet deep.

2176 *Mr. Dibdin*: Depth must be governed by local conditions. As a general rule it will be convenient to have them from 3 to 4 feet deep. Laboratory experiments with a bed 8 feet deep showed unexpectedly better results in the lower depths than in the upper, judging from the analyses of samples taken at each foot in depth.

7050 *Col. Harding*: At Leeds, coke beds were 5 and 6 feet deep respectively (primary and secondary), and clinker
7092 beds were both 3 feet deep. The deeper beds gave the better results.

7127-33 The beds were working for two years, but does not think experiment was conclusive.

Fifth Report: Appendix I.

20770 *Messrs. Raymond Ross & Pickles* (*Burnley*): No experience of beds more than 3 feet deep. Thinks that beds much deeper than 3 feet would not work efficiently.

21142 *Mr. Bolton* (*Heywood*): Bed should not be more than 4 feet deep.

21355-66 Rate of purification faster in upper layers. This view is based upon method of distribution at Heywood which is not satisfactory. Seems to think that, with proper distribution, there might be advantage in deeper beds.

21461 *Mr. Kershaw* (*Rotherham*): Beds 3 feet and 4 feet deep give good results. Had no experience of other depths.

21652 *Mr. Campbell* (*Huddersfield*): Should not be deeper than 4 feet. Conclusion after careful experiments with beds varying from 3 feet to $4\frac{1}{2}$ feet deep. Deterioration in results with beds over 4 feet (21833-8).

CONTACT BEDS.

(46.) May the Depth of Contact Beds vary within Certain Limits: What Limits are Permissible (*continued.*)

22005 *Mr. Harrison* (*Leeds*): At Leeds, contact beds varying in depth from 3 feet to 6 feet have been used.

Within these limits, primary and secondary beds 6 feet deep gave somewhat better results than the shallower beds. This, however, may have been due to differences in material, grading, and method of working.

22450 *Mr. Valentine* (*Oldham*): At Oldham, the beds vary between limits of 1½ feet and 3 feet deep. Has had no experience of beds deeper than 3¼ feet. Within the limits mentioned, a cubic yard of the shallowest bed would be quite as efficient as a cubic yard of deepest bed (22494).

22643 *Dr. Wilkinson* (*Oldham*): As a result of special experiments and other observations, he considers that beds above 3 feet deep would not give such satisfactory results as shallower beds. There is more rapid purification in the upper layers.

22792 *Mr. Fowler* (*Manchester*): Yes: has seen contact beds successfully at work varying from 15 inches in depth to 13 feet. With a depth beyond 4 feet, care must be taken that hard and fairly large material is used to prevent crushing and excessive capillary attraction.

22968-9 Within a limit up to 4 feet in depth, a cubic yard of the shallow bed would be as efficient as a cubic yard of the deeper bed.

23229 *Mr. Carter Bell* (*Salford*): No contact beds at Salford; but thinks that limits of depth should be from 4 to 8 feet.

23559 *Mr. Wike* (*Sheffield*): Should not be much deeper than 5 feet. Beds with a depth of 3 feet to 4 feet give better aeration than deeper beds.

24283 *Mr. Wilkinson* (*Manchester*): Probably 2 feet to 6 feet are permissible limits, dependent to some extent on fineness of material. Deeper bed should have coarser material.

26076 *Messrs. Willcox & Raikes*: Yes, but it is difficult to aerate contact beds more than 3 feet deep. Shallower beds involve increased cost in construction owing to increased area of floor and length of under drains.

(47.) WHAT IS THE MOST CONVENIENT SIZE FOR A CONTACT BED. CONTACT BEDS.

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20771 20932 *Messrs. Raymond Ross & Pickles* (*Burnley*): Of a size that will admit of the bed being filled by the available flow of liquid in about two hours. This allows a sufficient period of resting if beds are not filled more than twice a day.

21143 *Mr. Bolton* (*Heywood*): From one-ninth to one-twelfth of the total area should be the unit.

21462 *Mr. Kershaw* (*Rotherham*): Of such a size that they can be filled in one hour or less.

21653 *Mr. Campbell* (*Huddersfield*): About one acre.

22006 *Mr. Harrison* (*Leeds*): Half-acre, for large volumes of sewage.

22451 *Mr. Valentine* (*Oldham*): Thinks no bed should be much beyond one-third of an acre in area, and that it should be as near as possible in the form of a square.

22644 *Dr. Wilkinson* (*Oldham*): Beds should be capable of being filled in one or one and a-half hours.

22793 *Mr. Fowler* (*Manchester*): This depends upon quantity of liquid to be treated. Probably one acre about the largest size that can be conveniently worked in one unit. Each unit should be of a size which can be filled without seriously shortening rest period. A dosing tank is a useful device in small installations.

23560 *Mr. Wike* (*Sheffield*): Of such a size that they can be filled within one hour. Beds half-an-acre in area and three to four feet deep convenient to work.

CONTACT BEDS.

(47.) WHAT IS THE MOST CONVENIENT SIZE FOR A CONTACT BED (*continued*),

24284 *Mr. Wilkinson* (*Manchester*) : Of such a size as will admit of bed being filled in one hour at normal dry weather rate. Total area must, however, be divided into sufficient number of units, due regard being paid to maximum and minimum rates of flow, increased volume to be treated in wet weather, necessity for rest, cleaning repairs, etc.

26077 *Messrs. Willcox & Raikes*: Contact beds should not be so large that they take more than one hour to fill during the period of minimum flow.

(48.) WHAT ARE THE BEST FILTERING MATERIALS FOR CONTACT BEDS.

CONTACT BEDS.

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Mr. D. Cameron (Exeter) : Furnace clinker gave best results. (Several experiments with different materials.)

Important thing is to have smooth surfaces for liquid to flow over, without cavities that will hold the water. Coal, if broken cubically with smooth surfaces, is a very good material.

Thinks uniformity in size very important.

Mr. Dibdin : Prefers coke, clinker, or ballast, because of the rougher surfaces. Other materials which can be used are broken granite, slates, chalk, etc.

The efficiency of a material depends on the character of its surface.

Sir H. Roscoe : From experience at Manchester, is inclined to think that cinders are a better filtering material than coke.

Col. Harding : From the point of view of disintegration and consolidation, broken granite of perfectly even size would seem an ideal material, but would be very costly in most places.

Equally sized gravel would do very well ; and indeed any material of equal size, cubical or spherical in form, and not easily disintegrable. Porosity not very important.

Dr. Frankland : Clinker is a very efficient material. In every place there is some local material which could be used. " Saggers " from the potteries is magnificent material (very porous and very hard), and an unlimited quantity is available.

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Messrs. Raymond Ross & Pickles (Burnley) : Prefer hard burnt clinker.

Mr. Bolton (Heywood) : Well-burned furnace and destructor clinker.

CONTACT BEDS.

(48.) WHAT ARE THE BEST FILTERING MATERIALS FOR CONTACT BEDS (*continued*).

21463 *Mr. Kershaw* (*Rotherham*): Coal has done good work, and after three years shows little sign of disintegration. Clean, well-burnt clinker is as good as anything, and "saggers" and other pottery waste which would be available in some districts would do well.

21654 *Mr. Campbell* (*Huddersfield*): Good hard clinker that will not disintegrate.

22007 *Mr. Harrison* (*Leeds*): Has only had experience of destructor clinker and coke, and, of these, prefers hard furnace coke.

22452 *Mr. Valentine* (*Oldham*): Of the two materials tried, mill ashes and destructor clinker, he prefers the latter as it disintegrates much less readily. No experience of other materials.

22645 *Dr. Wilkinson* (*Oldham*): Clinkers from refuse destructor have been found a suitable material. It is hard, and appears to disintegrate very slowly.

22794 *Mr. Fowler* (*Manchester*): Experience at Manchester is that hard furnace clinker is the best material. If properly sized, other materials, such as broken Staffordshire bricks, broken "saggers," gravel, and the like, should do equally as well as clinker.

23231 *Mr. Carter Bell* (*Salford*): Crushed clinkers about a quarter of an inch in diameter. (No practical experience, 23235).

23561 *Mr. Wike* (*Sheffield*): Most satisfactory materials have been found to be (1) hard clinker from steel works, (2) refuse destructor clinker, and (3) screened boiler clinker.

2428 *Mr. Wilkinson* (*Manchester*): Very best filtering material is broken brick or stone of the hardest character. Very rarely possible to obtain this at reasonable cost.

An efficient material, easily obtainable, is hard, well vitrified, furnace clinker. Quarry refuse, properly broken, is also suitable and not costly.

(48.) WHAT ARE THE BEST FILTERING MATERIALS FOR CONTACT BEDS (*continued*). CONTACT BEDS.

Dr. Letts: Gives results of comparative experiments at Belfast with different materials, viz., broken brick, freestone, whinstone, clinker, coke, and limestone. Best results were obtained from broken brick material, and the worst results with the freestone.

Messrs. Willcox & Raikes: Crushed saggers from potteries possess all the essential qualities of good filtering material, being hard and proof against disintegration. Crushed blue bricks, clinker, granite or flints are also satisfactory.

Important to use local material wherever possible owing to heavy cost of carriage.

CONTACT BEDS

(49.) WHAT SIZE SHOULD THE FILTERING MATERIAL BE FOR CONTACT BEDS, AND SHOULD IT BE GRADED IN THE BEDS.

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2091 *Mr. D. Cameron (Exeter)* : Attaches great importance to uniformity in size of material. Seems to prefer fine material.

p. 117 *Mr. Dibdin : For coarse beds :* material which will pass 4-inch mesh and be rejected by $\frac{1}{2}$-inch mesh, *i.e.*, ordinary coarse coke or coarsest burnt ballast.

For fine beds : Material which has passed $\frac{1}{2}$-inch mesh, or, better still, $\frac{3}{8}$-inch mesh, and rejected by $\frac{1}{16}$-inch mesh.

p. 271 *Mr. Baldwin Latham* : Essential that contact beds should be as near as possible of a uniform composition throughout, and not made of coarser material at the bottom and finer at the top.

7165–6 *Col. Harding :* Most important that material should be of equal size. Coarse material necessary where crude sewage is passed on to bed.

9985–6 *Dr. P. F. Frankland :* The material should be so far graded that the finer material is on the top so as to arrest suspended matter as far as possible.

The use of comparatively fine material, especially for the first bed (at Manchester), was found to be of great advantage.

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20773 *Messrs. Raymond Ross & Pickles (Burnley)* : All material should be both washed and screened. For primary beds, material retained by screen of $\frac{1}{2}$-inch mesh is used at Burnley : for secondary beds, material passing through $\frac{1}{2}$-inch mesh and retained by $\frac{1}{8}$-inch mesh. No attempt is made to grade material in beds.

(49.) What Size should the Filtering Material be for Contact Beds and should it be graded in the Beds (*continued*). CONTACT BEDS.

21145 *Mr. Bolton (Heywood)*: First contact beds: Pass 1½-inch mesh, and rejected by ½-inch mesh. Second contact beds: Pass ½-inch mesh, and rejected by ¼-inch mesh.

Material should not be graded; but there should be a small quantity of fine material near inlet to arrest suspended matter

21464 *Mr. Kershaw (Rotherham)*: Primary contact bed after tank treatment: Material passing 1¼-inch screen, and retained on 1-inch screen. Second contact bed: Material from ⅝ inch to ⅛ inch. There should be layer of finer material on top.

21655 *Mr. Campbell (Huddersfield)*: Material should be graded. Filter, 3 feet 6 inches deep Top 6 inches: fine clinker—¼ inch to ⅝ inch. Middle 2 feet 6 inches: medium clinker—¼ inch to 3 inches. Bottom 6 inches: rough clinker—5 inches to 6 inches.

22008 *Mr. Harrison (Leeds)*: Size of material should be as small as conditions will allow, *e.g.*, if liquid contains little or no suspended matter, clinkers or coke-breeze with only dust taken out would do: otherwise, material for primary bed should be 1 inch in diameter or more; the secondary bed may be of much smaller material. No grading is necessary, except a layer of coarse material over drains, and in some cases a very fine surface layer.

22453 *Mr. Valentine (Oldham)*: Oldham beds filled with clinker passing ½-inch mesh. Small material is likely to cause clogging.

22646 *Dr. Wilkinson (Oldham)*: At Oldham, all material passing a ¼-inch mesh is rejected. The material is not graded.

22795 *Mr. Fowler (Manchester)*: Within limits, the finer the material the better. The limit of fineness is probably about ⅛ inch. Systematic grading is not necessary: there must, however, be coarse material at bottom to effect good drainage; and a layer of finer material on top to effect even distribution and arrest coarse suspended matters is of advantage.

23232 *Mr. Carter Bell (Salford)*: ¾-inch graded to 1 foot of 2 inches at bottom. (No practical experience of contact beds).

CONTACT BEDS.

(49.) What Size should the Filtering Material be for Contact Beds, and should it be graded in the Beds (*continued.*)

23562 *Mr. Wike* (*Sheffield*): Best results from graded beds. Following 3-foot bed has given satisfactory results with settled sewage. Furnace clinker, top 3 inches, $\frac{1}{4}$-inch to $\frac{1}{8}$-inch gauge; next 9 inches, $\frac{3}{4}$-inch to $\frac{1}{4}$-inch gauge; lower 24 inches, $1\frac{1}{2}$-inch to $\frac{3}{4}$-inch gauge.

Distribution channels should be cut in the material forming the top layer and lined with fine screenings.

24286 *Mr. Wilkinson* (*Manchester*): Primary beds: Material passing 2-inch, and rejected by $\frac{1}{4}$-inch mesh.

Secondary beds: Material passing 1-inch, and rejected by $\frac{1}{8}$-inch mesh. Grading is costly, and is not necessary.

26079 *Messrs. Willcox & Raikes.*—Best results obtained with material passing $\frac{1}{2}$-inch mesh and retained on $\frac{1}{4}$ inch. This applies to saggers (26182).

26182 The bulk of the material should be of the same size.

(50.) HOW SHOULD THE BOTTOM OF THE CONTACT BED BE CONSTRUCTED.

Interim Report: Vol. II. (*Cd.* 686), 1902.

ge 271 *Mr. Baldwin Latham*: Important that drains should not be so laid as to cause the sewage to pass immediately through the filtering material into them. A method of construction should be adopted by which the drain is left full of purified effluent after bed is emptied.

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74 *Messrs. Raymond Ross & Pickles* (*Burnley*): There should be good fall towards outlet chamber. Drains should be glazed and socketed; earthenware pipes with ½-inch holes three-quarters of the way round the pipe. For secondary beds, unglazed field pipes with butt joints have been found satisfactory.

146 *Mr. Bolton* (*Heywood*): Of impervious material, slightly inclined towards outlet, and well drained.

465 *Mr. Kershaw* (*Rotherham*): Should be fairly smooth or even with a fall from every part to outlet. Perforated pipes or draining tiles should be arranged at intervals over floor, and the whole covered with layer of rough material.

356 *Mr. Campbell* (*Huddersfield*): Of concrete, with a slight fall, and under-drained by perforated pipes.

154 *Mr. Valentine* (*Oldham*): No preference for any particular form of construction, so long as the bed and the drains can empty themselves by gravitation when the valves are open.

347 *Dr. Wilkinson* (*Oldham*): At Oldham, there are two rows of drain pipes in the bottom of the bed, and there is a gradual slope towards these.

96 *Mr. Fowler* (*Manchester*): Bottom should be constructed so as to effect the freest possible drainage. Sunk drain channels in concrete covered with perforated tiles over which there are plenty of large clinkers—or preferably big flints from gravel—are very efficient.

CONTACT BEDS.

(50.) How should the Bottom of the Contact Bed be constructed (*continued*)

23233 *Mr. Carter Bell (Salford)* : With perforated tiles.

23563 *Mr. Wike (Sheffield)* : With concrete, if a natural bottom is not available. It should slope to the outlet and the drains should be open pipes or channels, with loose perforated covers. The pipes or channels should remain full of effluent when bed is emptied.

24287 *Mr. Wilkinson (Manchester)* : In rectangular beds, floors should be sloped from sides to centre; with square beds, the underdrains should converge to a collecting drain at one side. Floor should be of concrete in which the drains should be embedded and covered with tiles even with the concrete.

26080 *Messrs. Willcox & Raikes* : Of concrete, with drains at intervals for carrying off the effluent.

(51.) IS IT GENERALLY DESIRABLE THAT SEWAGE SHOULD BE SUBJECTED TO SOME FORM OF TANK TREATMENT BEFORE BEING PUT ON CONTACT BEDS.

Interim Report : Vol. II. (Cd. 686), 1902.

2176 *Mr. Dibdin* : Suggests that screening (for removal of rags, etc.) is all that is necessary.

7209 *Col. Harding* : Leeds experiments show that it is far better to have preliminary treatment for reducing suspended solids. Beds act very readily on dissolved impurities, but very slowly upon suspended impurities.

7518–20 *Mr. G. R. Strachan* : Preliminary treatment for removal of solids—preferably settling or septic tanks—is desirable, though not essential.

Page 530 *Dr. P. F. Frankland* : Advantages of preliminary settlement are :—

(*a*) Removal of suspended solids.
(*b*) Comparative uniformity of sewage reaching beds.
(*c*) Resolution of large proportion of suspended solids and consequent prevention of much sludge.
(*d*) Resolution of some dissolved organic matters.

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20775 *Messrs. Raymond Ross & Pickles (Burnley)* : Yes.

21147 *Mr. Bolton (Heywood)* : Yes.

21466 *Mr Kershaw (Rotherham)* : Yes, it is very necessary : otherwise, the beds would choke up rapidly.

21657 *Mr. Campbell (Huddersfield)* : Yes.

(51.) Is it generally desirable that Sewage should be subjected to some form of Tank Treatment before being put on Contact Beds (*continued.*)

2200 *Mr. Harrison* (*Leeds*): Yes, the primary object being to reduce the amount of solids so as to minimise loss of capacity. Incidentally, better nitrated filtrates are produced.

22455 *Mr. Valentine* (*Oldham*): Yes, decidedly so.

2264 *Dr. Wilkinson* (*Oldham*): Certainly desirable for Oldham sewage.

22797 *Mr. Fowler* (*Manchester*): Yes, unless the beds are specially constructed to effect the aerobic digestion of sludge.

23564 *Mr. Wike* (*Sheffield*): Yes.

24288 *Mr. Wilkinson* (*Manchester*): Yes.

26081 *Messrs. Willcox & Raikes*: Yes.

(52.) WHAT PERIODS OF FILLING, STANDING FULL; EMPTYING, AND STANDING EMPTY ARE BEST IN PRACTICAL WORKING FOR (*a*) PRIMARY BEDS AND (*b*) SECONDARY BEDS.

CONTACT BEDS.

Interim Report : Vol. II. (*Cd.* 686) 1902.

2013 *Mr. D. Cameron* : Nothing gained by more than one hour contact with Exeter sewage.

2176 (p. 119) *Mr. Dibdin* : About two hours' contact allowed in the Sutton beds.

3891–8 For coarse beds, there should be only two fillings per day as a rule. They can be worked in three fillings, but not continuously. Period of contact would be two hours : filling and emptying, about one hour each. Remainder of period, resting. There should not be less than four hours' resting empty after each contact.

3777–81 *Sir Henry Roscoe* : His experience shows that best results were obtained when beds were resting full 20 per cent. of time and aerating 60 per cent. One hour's contact sufficient.

7053 *Col. Harding* : Experiments at Leeds showed that two hours' contact was most effective, confirming Mr. Dibdin's experience.

7054 7057 One hour for filling, and one hour for emptying convenient periods. Speed for filling need only be limited by the question of distribution.

7055 The longer the resting period, the better the results. Under normal conditions, three fillings per day (cycles of 8 hours) were found convenient ; but there would be advantage in giving only one filling per day normally.

Fifth Report : Appendix I.

20776 *Messrs. Raymond Ross & Pickles* (*Burnley*) : Most satisfactory for both primary and secondary beds is filling, about two hours ; contact, about two hours. Beds should stand empty for not less than two hours between fillings.

21148 *Mr. Bolton* (*Heywood*)

Primary beds.—	Filling	1 hour
	Standing full	2 hours
	Emptying	½ hour
	Resting	4½ hours
Secondary beds.—	Filling	½ hour
	Standing full	2 hours
	Emptying	½ hour
	Resting	5 hours

CONTACT BEDS.

(52.) What Periods of Filling, Standing Full, Emptying, and Standing Empty are best in practical working for (*a*) Primary Beds and (*b*) Secondary Beds (*continued.*)

21467 *Mr. Kershaw* (*Rotherham*): Three fillings per day in 8-hour cycles, as follows:—

Filling	1 hour
Standing full	2 hours
Emptying	1 hour
Resting	4 hours

No material benefit from longer than 2 hours' contact.

21658 *Mr. Campbell* (*Huddersfield*):

Primary beds.—

Filling	1 hour
Standing full	2 hours
Emptying	1 hour
Resting	4 hours

Secondary beds.—A similar cycle is given at Huddersfield.

22010 *Mr. Harrison* (*Leeds*): At Leeds, for both primary and secondary beds, the method of working is usually—

Filling	1 hour
Standing full	2 hours
Emptying	1 hour
Standing empty	4 hours

An increased purification is obtained with increased periods of rest, but very little advantage, if any, by increasing period of contact.

22456 *Mr. Valentine* (*Oldham*): Filling not more than $1\frac{1}{2}$ hours.

Primary beds.—Standing full, varies at Oldham from 1 to 5 or 6 hours. Length of contact must depend upon age of bed, time of the year, day of the week, time of the day, strength of tank liquor.

Emptying, $1\frac{1}{2}$ hours.

Resting, 2 to 6 hours, depending upon the factors above mentioned.

Secondary beds.—The period of standing full for secondary beds would depend upon the character of the liquid from the primary bed. It may be sufficient to fill the bed and then immediately proceed to stream it through; and in any case not more than one hour's contact would be necessary.

22649 *Dr. Wilkinson* (*Oldham*):

Filling	$1\frac{1}{2}$ hours
Standing full	2 to 3 hours
Resting	2 to 6 hours

22798 *Mr. Fowler* (*Manchester*): In general, after the bed is once matured, the period of rest is more important than the period of contact, and the total time occupied in twenty-four hours in filling, standing full and emptying should not exceed the total of the period of rest. With increase in dilution of the tank liquor due., *e.g.*, to storm water, the period of contact may be reduced to a minimum. (These remarks also apply to secondary beds, but these can be worked more rapidly than primary beds.)

With new beds prolonged periods of contact, (*e.g.* 24 hours) have been found advantageous.

23564* *Mr. Wike (Sheffield)*: For both primary and secondary beds, 8-hour cycles, viz.—

Filling	1 hour
Standing full	1 to 2 hours
Emptying	1 hour
Resting	to complete 8 hours

Primary beds not more than three fillings per day. Four fillings can be given to secondary beds for short periods.

24289 *Mr. Wilkinson (Manchester)*:

For primary beds.—Filling - 1 hour
Standing full - 2 hours
Emptying - 1 hour
Resting, remainder of period according to the cycles in which the bed is worked.

For Secondary beds.—These may be worked at three times the rate of working of primary beds.

26082 *Messrs. Willcox & Raikes*: For both primary and secondary beds—

Filling	Not more than 1 hour
Standing full	Nil
Emptying	As quickly as possible
Standing empty	As long as possible

CONTACT BEDS.

(53.) HOW SHOULD CONTACT BEDS BE FILLED AND EMPTIED.

Interim Report : Vol. II. (Cd. 686), 1902.

120 *Mr. Dibdin :* In emptying, first portion should not be allowed to rush out too rapidly.
4001 Beds should be filled as rapidly as possible, and emptied as slowly as possible.

4548 *Mr. Baldwin Latham :* Beds must be filled quickly, so as to retain in the filter as much air as possible.

7051, 7143 *Col. Harding :* Filling should be as rapid as possible. Emptying quickly also desirable so as not to interfere
7054 with resting period.
7052 Most convenient plan of distribution was found in providing channels in the material itself, and turning them over from time to time, so varying their position.

Fifth Report : Appendix I.

20777 *Messrs. Raymond Ross & Pickles (Burnley)*: For filling, troughs six to eight feet apart fixed in surface, afford perfect distribution combined with moderate aeration. Beds are emptied as quickly as possible by opening valves to fullest extent.

21149 *Mr. Bolton (Heywood)* : Under personal control.

21468 *Mr. Kershaw (Rotherham)* : Observes no difference whether filters are filled by half pipes on surface, or whether liquid is run direct on to the material. Beds should discharge steadily at first until about a foot or so has run off, and then valve should be opened to fullest extent.

21659 *Mr. Campbell (Huddersfield)* : Fed by means of distributing troughs ; emptied by a valve at foot of bed.

22011 *Mr. Harrison (Leeds)* : Filled as quickly as possible with even distribution and without disturbing surface. Grips in the surface about three feet apart and connected at intervals are most effective for even distribution. In emptying, the liquid should flow out at an even rate.

(53.) How should Contact Beds be filled and emptied (*continued.*) CONTACT BEDS.

22650 *Dr. Wilkinson* (*Oldham*): At Oldham, beds are filled either from wood or pipe channels on the surface of the bed, crossing it or radiating from one point. The beds are emptied slowly at first, and when about half empty, the valves are fully opened.

22799 *Mr. Fowler* (*Manchester*): Filling should be, as far as possible, equably from the top, and emptying should also be as equably as possible. Slow drawing off is advantageous, as it, to a large extent, prevents the washing out of suspended matters.

23565 *Mr. Wike* (*Sheffield*): Filled as steadily as possible evenly over the surface. Surface channels found to be best means of distribution. Emptying should also be steady.

24290 *Mr. Wilkinson* (*Manchester*): Filled as far as possible evenly from above, and discharged in the same way from below. Lateral filling not desirable.

26083 *Messrs. Willcox & Raikes*: As rapidly as possible.

CONTACT BEDS.

(54.) VIEWS AS TO AUTOMATIC GEAR FOR FILLING AND EMPTYING CONTACT BEDS.

Fifth Report : Appendix I.

20778 *Messrs. Raymond Ross & Pickles* (*Burnley*) : Automatic apparatus an unnecessary expense as personal supervision is, in any case, necessary. It is very liable to get out of order, it takes no notice of condition of bed, and it is not adapted to variations in flow of sewage.

21660 *Mr. Campbell* (*Huddersfield*) : No automatic gear at present on the market gives satisfactory results.

22012 *Mr. Harrison* (*Leeds*) : Seems to object somewhat to automatic gear on account of its inapplicability to varying conditions.

22457 *Mr. Valentine* (*Oldham*) : Automatic gear is apt to get out of order, and is open to the objection that it is invariably adjusted to rigid times of contact, etc.

Manual labour is, in the long run, cheaper, safer, and more reliable.

22800 *Mr. Fowler* (*Manchester*) : Has had considerable experience of automatic gear, and sees no advantage in its use in large works, where skilled supervision must be provided in any case. Some simple mechanism might be advantageous in small works, chiefly on economic grounds, but even then it must have frequent personal attention. Automatic gear not adaptable to varying conditions.

23866 *Mr. Wike* (*Sheffield*) : Efficiency of automatic gear largely depends upon uniform flow and strength of sewage.

24291 *Mr. Wilkinson* (*Manchester*) : Automatic gear is liable to derangement, and can only be partially applied. Human control is desirable, especially in the matter of filling the beds.

24333–4 Automatic gear wants personal supervision, and is only useful in the case of any small works where the whole service of even one man cannot be afforded.

26084 *Messrs. Willcox & Raikes* : Automatic gear is a good substitute for manual labour on small works ; but control by an intelligent manager is far better.

(55.) WHAT AMOUNT OF TANK LIQUOR PER CUBIC YARD OF FILTERING MATERIAL CAN, IN PRACTICE, BE PROPERLY TREATED IN A PRIMARY CONTACT BED IN TWENTY-FOUR HOURS. CONTACT BEDS.

Interim Report : Vol. II. (Col. 686), 1902.

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17. *Mr. Dibdin :*

At Barking. Chemically precipitated effluent : Fine bed 3 feet deep, one acre in area.
Amount treated—1,000,000 gallons per day.

At Sutton. Strong domestic screened sewage. Coarse bed, 3 feet deep.
Amount treated—1,000,000 gallons per acre per day. Prolonged experience, however, points to a working rate, including rest periods, of 750,000 gallons per acre per diem.

At Leeds. Sewage and trade effluents. Beds 4½ feet deep.
Amount treated (six months)—770,000 gallons per acre per day.

Fifth Report : Appendix I.

Messrs. Raymond Ross & Pickles (Burnley) : Normally, 90 gallons per cubic yard (with two fillings) per twenty-four hours. When strength of tank liquor falls below ·400 parts per 100,000 of albuminoid ammonia, and 7·000 parts per 100,000 of oxygen absorbed (in four hours), about 135 gallons per cubic yard can be treated.

Mr. Bolton (Heywood) : Found that three fillings per day, equalling 100 gallons per cubic yard, with a septic tank liquor containing .35 parts of albuminoid nitrogen and absorbing 5·25 parts of oxygen in four hours, gave a percentage purification of fifty on the oxygen figure, and thirty-six on the albuminoid nitrogen.

Not practicable to give a varying contact with varying strengths of sewage.

Mr. Campbell (Huddersfield) : Amount depends on strength and nature of the sewage, and on the condition of the beds.

At Huddersfield.

Chemically precipitated sewage (7·0 parts per 100,000 suspended solids)	-	156 galls per c. yd.
Septic tank liquor (13·2 parts per 100,000 suspended solids)	- - -	126 ,, ,,

Beds 3½ feet deep. Three fillings a day.

Mr. Harrison (Leeds) : A primary bed, when new, and receiving three fillings per day of crude sewage at Leeds treated about 200 gallons per cubic yard per day. After two years it would only treat about sixty-six gallons per cubic yard. Analytically, results were satisfactory throughout the whole period.

Another bed, treating septic tank effluent, and resting one week in every four, treated an average of about 120 gallons per cubic yard at first, but four years later, only treated an average of fifty-four gallons. During past two years, this bed has treated an average of sixty-five gallons per cubic yard with really excellent results.

(55.) What Amount of Tank Liquor per Cubic Yard of Filtering Material can, in practice, be properly treated in a Primary Contact Bed in Twenty-four Hours (*continued*).

22458 *Mr. Valentine* (*Oldham*): With a tank liquor which absorbs 3½ parts in 100,000 of oxygen in four hours from permanganate, and a bed two or three years old, between 120 and 140 gallons per cubic yard per diem could be efficiently treated. With a less purified effluent (absorbing eight to ten parts of oxygen), only eighty to ninety-five gallons could be treated per cubic yard.

22652 *Dr. Wilkinson* (*Oldham*): With an average tank effluent, of, say, three to five grains of oxygen in 100,000 by four hours' test, not more than 100 gallons per cubic yard per day can economically, having regard to the life of the bed, be treated on a contact bed. This applies to single contact.

22801 *Mr. Fowler* (*Manchester*): The amount depends upon the character of the sewage and the size of the filtering material. His general conclusion is that, to obtain a really first-class effluent, one cubic yard of material should be provided per person. This can be arranged in any way to suit the particular circumstances, single contact, double contact, or continuous percolation.

23153-4 The above proportion would provide for storm flow and also allow a margin for occasional resting of beds.

5601-3 Interim Report. In July, 1900, experience at Manchester pointed to average speed, for primary bed, of 750,000 gallons per acre per day (allowing Sundays rest and one week's rest per month).

23567 *Mr. Wike* (*Sheffield*): With beds three to four years old, and three fillings per day, 120 gallons per cubic yard. Amount must vary with quality of tank liquor.

26085 *Messrs. Willcox & Raikes*: Less than 200 gallons per cubic yard per day. Quality of tank effluent affects the amount that can be dealt with.

(56.) WHAT AMOUNT OF LIQUID FROM A PRIMARY BED CAN IN PRACTICE BE TREATED ON A SECONDARY BED PER CUBIC YARD OF FILTERING MATERIAL PER TWENTY-FOUR HOURS.

CONTACT BEDS.

Fifth Report: Appendix I.

0 *Messrs. Raymond Ross & Pickles* (*Burnley*): Bed in operation for five and a quarter years is dealing with 90 gallons per cubic yard per twenty-four hours in two fillings.

2 *Mr. Bolton* (*Heywood*): About one and a half times the quantity treated on the primary bed. Result of actual experiments (21274).

2 *Mr. Campbell* (*Huddersfield*): 166 gallons per cubic yard at Huddersfield. (Beds three and a half feet deep. Three fillings per day). It would be possible to treat a larger amount.

4 *Mr. Harrison* (*Leeds*): The practice at Leeds is to treat the liquid on the secondary bed at the same rate as on the corresponding primary bed.

9 *Mr. Valentine* (*Oldham*): Very little experience, but thinks that a secondary bed ought to take nearly three times the quantity passed through primary beds.

1 *Mr. Fowler* (*Manchester*): This amount depends upon the percentage purification effected by the primary bed. At Manchester the first contact effluent is generally non-putrefactive, and this can be efficiently treated on a secondary bed of half the area of the first bed.

-5 rim ort. Primary bed deals with 750,000 gallons per acre per day: therefore, secondary bed would work at rate of 1,500,000 gallons per acre per day.

8 *Mr. Wike* (*Sheffield*): Generally speaking, with three fillings per day, 160 gallons per cubic yard.

6 *Messrs. Willcox & Raikes*: Contact beds at Hanley of little use if filled more than two or three times a day even with partially purified sewage.

CONTACT BEDS.

(57.) CAN THE RATE OF WORKING OF CONTACT BEDS BE INCREASED IN TIMES OF STORM WITHOUT IMPAIRING THE EFFICIENCY OF THE BEDS OR THE QUALITY OF THE EFFLUENTS.

Interim Report: Vol. II. (Cd. 686), 1902.

p. 120 *Mr. Dibdin:* Yes, the work thrown upon the beds depends upon quantity of sewage matter, not on mere volume of water in which it is contained. With sewage one half the normal strength, beds will deal with double the quantity. At Sutton, beds have frequently been filled six or seven times a day during wet weather.

4493–5 *Dr. Rideal:* At Exeter, the result of passing about twice the dry weather flow through the beds and reducing the period for each filling was very unsatisfactory as regards the filtrate, but there was no permanent injury to the beds.

4507–11 *Mr. Baldwin Latham:* Storm water sewage, according to its strength, can be passed at a quicker rate through beds without impairing their efficiency.

7055 *Col. Harding:* Suggests that, with one filling a day in normal times, beds might be filled, in times of rain three times and even six times a day for short periods. No actual experience in the treatment of dilute sewage; considers that the first part of the storm diluted sewage should in any case receive fuller treatment (7093–9).

Fifth Report: Appendix I.

20781 *Messrs. Raymond Ross & Pickles (Burnley):* With Burnley sewage, the contact beds could not be filled more than three times a day without impairing the quality of the effluent. Normal working is two fillings per day.

21153 *Mr. Bolton (Heywood):* Yes, with storm water proper, if the suspended solids had been considerably reduced.

21663 *Mr. Campbell (Huddersfield):* Yes. First flush of storm sewage should not be allowed on beds; but, as the sewage becomes more dilute, beds may be filled five or six times per day.

(57.) Can the Rate of working of Contact Beds be increased in Times of Storm without impairing the Efficiency of the Beds or the Quality of the Effluents (*continued.*) **CONTACT BEDS.**

Mr. Valentine (*Oldham*): Yes. A well-settled tank effluent in storm times might be streamed directly through secondary beds for hours at a stretch. Has found, by actual experience, that this can be done without any ill effects either as regards efficiency or capacity (22493).

Dr. Wilkinson (*Oldham*): Yes, a flow of weak sewage through a filter bed occasionally has often very beneficial results.

Mr. Fowler (*Manchester*): On the basis of one cubic yard of filtering material per person, storm water can be passed through the beds.

Mr. Wike (*Sheffield*): Probably, for short periods. (Question has not been closely investigated.)

Messrs. Willcox & Raikes: No, accelerated working will adversely affect quality of effluent. But provided bed is not clogged, accelerated working for short period does not necessarily affect results afterwards.

CONTACT BEDS.

(58.) MAY CONTACT BEDS IN TIME OF STORM BE USED AS STREAMING FILTERS, AND ARE THERE ANY ADVANTAGES IN SO WORKING THEM.

Interim Report : Vol. II. (Cd. 686), 1902.

Mr. Dibdin : Gives results of special experiments in streaming storm diluted sewage through contact beds, at Worcester Park and Sutton :—

—	*Amount treated.*	*Period.*	*Percentage Purification.*
Worcester Park -	200,000 gallons. (Plant designed to deal with normal flow of 80,000 gallons per day.)	8 hours	Average for whole period. { 66 by alb. amm. test. 64 ,, oxygen absorbed test.
			End of period. { 75 by alb. amm. test. 71 ,, oxygen absorbed test.
Sutton -	(1.) 208,320 gallons. (Two beds, 186 sq. yds. each, 5¼ feet deep.)	9 hours	Average for whole period. { 29 by alb. amm. test. 27 ,, oxygen absorbed test.
			End of period. { 72 by alb. amm. test. 63 ,, oxygen absorbed test.
	(2.) 323,000 gallons. (Same beds.)	9¾ hours	Average for whole period. { 59 by alb. amm. test. 63 ,, oxygen absorbed test.
			End of period. { 81 by alb. amm. test. 71 ,, oxygen absorbed test.
	(3.) 397,440 gallons. (Same beds.)	12 hours	Average for whole period. { 58 by alb. amm. test. 55 ,, oxygen absorbed test.
			At end of period. { 63 by alb. amm. test. 64 ,, oxygen absorbed test.

In each case all suspended solids were removed by the filtration.

The Sutton beds on return to intermittent work gave a purification on alb. amm. of 83 per cent. and by oxygen absorbed, 77 per cent., with total removal of suspended solids.

3936-43 There was no reduction in capacity through working the beds as streaming filters. But Sutton is sewered on the separate system, and there is no road grit in the sewage to choke the beds

3944-5 Though there was a reduction in percentage purification, the quality of storm water effluent obtained by streaming through beds was on the whole quite equal to sewage effluent obtained by ordinary working.

Fifth Report : Appendix I.

20794 *Messrs. Raymond Ross & Pickles (Burnley)* : Consider this would be very detrimental to beds. Have found by actual experiments that streaming is detrimental both to the bed itself and to the quality of the filtrate (21045–7).

21164 *Mr. Bolton (Heywood)* : No advantage in working contact beds as streaming filters. With this system of working, there is great tendency for beds to choke near the inlet.

21673 *Mr. Campbell (Huddersfield)* : Should not be used as streaming filters unless they are constructed of coarse materials.

(58.) May Contact Beds in Time of Storm be used as Streaming Filters, and are there any Advantages in so working Them (*continued*).

22473 *Mr. Valentine* (*Oldham*): This has been done at Oldham and works extremely well. In ordinary circumstances the filters afterwards seem better and there is an appreciable increase in capacity.

In case of summer storm followed at once by fine, hot weather, two or three fillings subsequent to the storm water dosing give effluents of an unsatisfactory nature.

22662 *Dr. Wilkinson* (*Oldham*): Yes; and after being so used, and a rest, the results are better.

22813 *Mr. Fowler* (*Manchester*): Yes, but short contacts are better. Streaming requiring less attention, is useful in an emergency.

23578 *Mr. Wike* (*Sheffield*): Tried streaming for short periods with very dilute sewage without apparent detriment.

26100 *Messrs. Willcox & Raikes*: Contact beds converted into streaming filters either temporarily or permanently give improved results, provided the sewage is efficiently distributed over the surface.

(59.) IS THE AMOUNT OF SUSPENDED SOLIDS INCREASED IF THE BEDS ARE FILLED AND EMPTIED MORE FREQUENTLY IN STORM TIMES OR OTHER TIMES.

Fifth Report : Appendix I.

20793 *Messrs. Raymond Ross & Pickles (Burnley)* : Apparently not.

21163 *Mr. Bolton (Heywood)* : Only slightly.

21480 *Mr. Kershaw (Rotherham)* : No material visible increase has been noticed.

22472 *Mr. Valentine (Oldham)* : Yes, generally more than the average amount; but nearly all of a mineral nature.

22812 *Mr. Fowler (Manchester)* : No, except through clay passing through beds in early stages of storm.

26099 *Messrs. Willcox & Raikes* : Yes.

(60.) IS ONE CONTACT SUFFICIENT FOR THE CONVERSION OF CERTAIN TANK LIQUORS INTO A SATISFACTORY EFFLUENT. CONTACT BEDS.

Interim Report; Vol. II. (Cd. 686), 1902.

6554-7 *Mr. G. Chatterton*: Had experience of actual working of contact beds (two acres in extent) at Merton (Croydon Rural) sewage farm giving very satisfactory results by single contact after chemical precipitation. Typical analysis of filtrate—oxygen required to oxidise organic matter, ·091 grains per gallon.

6641-8 *Mr. R. A. Tatton*: Single filtration of settled sewage at Oldham gives uniformly satisfactory results. Beds have an area of 18,920 square yards, treat about 1,500,000 gallons per day, and have been working for two years.

7067 *Col. Harding*: Did not obtain at Leeds good enough results from single contact, either with lime-settled effluent or septic tank effluent. Results were only fair, and never reached Rivers Board standard.

Fifth Report: Appendix I.

20782 *Messrs. Raymond Ross & Pickles (Burnley)*: Do not know of any liquors which could be dealt with by one contact.

21154 *Mr. Bolton (Heywood)*: One contact sufficient for weak tank liquors in which the four hours' oxygen absorbed figure is as low as 2·5 parts per 100,000 and the albuminoid nitrogen ·20 One contact would reduce these to 1 part for the oxygen absorbed figure and ·1 for the albuminoid nitrogen.

21470 *Mr. Kershaw (Rotherham)*: Single contact cannot regularly be relied upon. Results for 1903 and 1904 (averages):

——	1903.			1904.		
	Tank Liquor.	Single Contact Filtrate.	Purification Per Cent.	Tank Liquor	Single Contact Filtrate.	Purification. Per Cent.
Oxygen absorbed . .	2·34	·96	59	3·65	1·49	59·18

CONTACT BEDS.

(60.) Is one Contact sufficient for the Conversion of certain Tank Liquors into a Satisfactory Effluent (*continued*).

21664 *Mr. Campbell* (*Huddersfield*): One contact sufficient for weak tank liquors, *e.g.*, heavy storm flows, and week-end and night flows. Tank liquors having oxygen absorption of 2–4 parts per 100,000 give effluent by one contact with from 0·5 to 1·4 parts per 100,000.

22015 *Mr. Harrison* (*Leeds*): Has never been able to produce a satisfactory filtrate with one contact.

22461 *Mr. Valentine* (*Oldham*): With a tank liquor absorbing 3½ parts in 100,000 of oxygen in four hours from permanganate, and a bed two or three years old, one contact would be sufficient to produce an effluent which would remain non-putrescent on incubating, and would rarely absorb as much as 1·25 parts of oxygen per 100,000.

22654 *Dr. Wilkinson* (*Oldham*): Yes, with, say, three hours' contact, and a tank effluent not exceeding 4–5 parts per 100,000 of oxygen by four hours' test. With a longer contact a satisfactory result can be obtained with a much worse effluent.

22801 *Mr. Fowler* (*Manchester*): With a sufficient area of fine material (? one cubic yard per person), one contact will often suffice, but prefers double contact.

(This answer apparently applies to sewage which has undergone thorough preliminary treatment in septic tanks, *see* 5578–81. Interim Report: Vol. II.)

23570 *Mr. Wike* (*Sheffield*)
23615 *Mr. Haworth* (*Sheffield*) } Assuming outfall is a river of fair size, consider single contact sufficient. The following is an average of analyses:—

—	Parts per 100,000.	
	Tank Liquor.	Effluent produced by Single Contact.
Oxygen absorbed in 4 hours	4·14	1·68
Ammoniacal nitrogen	2·70	1·44
Albuminoid „	·43	·17
Chlorine	10·57	10 42
Suspended solids	10·75	—
Nitrogen as nitrates and nitrites	—	·40

23839-42 Single contact effluents, however, are frequently putrescible, though only very slightly.

(60.) Is one Contact sufficient for the Conversion of certain Tank Liquors into a Satisfactory Effluent (*continued*). **CONTACT BEDS.**

84 *Dr. Letts:* The filtrates from the first beds in some experiments at Belfast were not sufficiently pure to go into a small and clean non-drinking water stream.

Nature of Sample.	Parts, per 100,000.*							Cubic Centimetres per Litre†		
	Nitrogen as :—				Oxygen Absorbed Test at 80°F.			Dissolved Gases.‡		
	Free Ammonia.	Albuminoid Ammonia.	Total Kjeldahl,	Nitrate.	3 Minutes.	4 Hours.	Incubator Test 3 Minutes.	Carbonic Anhydride.	Oxygen.	Nitrogen.
Screened and settled sewage	2·13	0·89	3·36	0·14	2·87	9·01	6·67	106·12	0·01	17·93
Effluent from upper bed -	1·55	0·52	2·36	—	1·64	4·74	3·55	115·51	0·00	19·14
„ „ lower bed -	1·04	0·26	59	0·03	0·92	2·62	1·38	111·39	0·03	20·00

* Mean of 12 series of analyses. † Mean of 6 series of analyses.

‡ The dissolved gasses also contained at times hydrogen and arsh gas in small quantities. These were determined, but are not included in the nitrogen.

088 *Messrs. Willcox & Raikes:* Have never found single contact sufficient to give satisfactory effluent.

CONTACT BEDS.

(61.) AT WHAT RATE OR RATES DO PRIMARY CONTACT BEDS AND SECONDARY CONTACT BEDS LOSE THEIR WATER-HOLDING CAPACITY.

Interim Report: Vol. II. (Cd. 686) 1902.

387 *Mr. D. Cameron (Exeter):*

Water capacity of bed, after filtering material was put in = 8,932 gallons, or ·39 of contents.

After 26 months' working, water capacity - - - = 6,349 „ ·28 „

After a rest, water capacity rose - - - - - = 7,170 „ ·32 „

3805 *Mr. Dibdin:* TABLE SHOWING CAPACITIES OF SUTTON COARSE GRAIN BEDS.

No. 1. Original Coarse Bed.

No. 2. Mixed Fine and Coarse Bed, stratified.

No. 3. Same as original Coarse Bed.

No. 4. Ditto.

Date of Measurement.	Area.	D'pth	Cubic Capacity in Cubic Feet.			Percentage.		Working Capacity in Gallons, per acre, per day.			
			Water.	Filtering Material	Total.	Water.	Filtering Material	One Filling daily.	Two Fillings daily.	Three Fillings daily.	—
	Sq'are yds.	Ft. In.									
No. 1.											
Aug. 22nd, 1897	186	5 3	2,796	6,011	8,807	32	68	457,378	914,756	1,372,134	Commenced working November 21st, 1896.
Oct. 6th, 1898			1,054	7,753	8,807	12	88	171,518	342,036	514,554	
Nov. 27th, 1898			1,132	7,675	8,807	13	87	185,811	371,622	557,433	
*Dec. 5th, 1898			1,528	7,279	8,807	17½	82½	250,129	500,258	750,487	
Jan. 11th, 1899			1,246	7,561	8,807	14	86	200,104	400,208	600,312	
No. 2.											
June 3rd, 1897	186	5 3	2,480	6,327	8,807	28	72	400,206	800,412	1,200,618	Commenced working June 3rd, 1897,
Oct. 13th, 1898			1,213	7,594	8,807	13½	86½	192,957	385,914	578,871	
Nov. 30th, 1898			1,053	7,754	8,807	12	88	171,518	342,036	514,554	
No. 3.											
July 23rd, 1897	186	5 3	2,720	6,087	8,807	31	69	443,085	886,170	1,329,255	Commenced working July 23rd, 1897.
Oct. 12th, 1898			1,496	7,311	8,807	17	83	242,983	485,966	728,949	
Dec. 3rd, 1898			1,475	7,332	8,807	17	83	242,983	485,966	728,949	
Jan. 7th, 1899			1,643†	7,164	8,807	18½	81½	264,422	528,844	793,266	
No. 4.											
Apr. 30th, 1898	186	5 3	2,880	5,927	8,807	32¾	67¼	468,097	936,194	1,404,291	Commenced working April 30th, 1898.
Oct. 11th, 1898			2,261	6,546	8,807	25½	74½	364,473	728,946	1,093,419	
Dec. 5th, 1898			2,735	6,082	8,807	31	69	443,085	886,170	1,329,255	
Jan. 10th, 1899			2,570	6,237	8,807	29¼	70¾	418,072	836,144	1,254,216	

* After one week's rest. † January 14th, 1899. Aftr one week's rest, 2,098 cubic feet.

7063 *Colonel Harding:* Gives the following Table showing the variations in capacity of contact beds at Leeds.

No. 1 Rough Contact Bed.

Capacity before putting in Coke - - - - Gals. 174,800
Original water capacity after putting in the Coke - - 83,300

Date	Gals.		Ratio per cent. of water capacity of total capacity.
1897 1 Oct.	83,300	Crude sewage (3 fillings)	47·6
1 Nov.	74,000	42 grains per gal. of suspended solids	42·3
1 Dec.	64,000	„	36·6
1898 1 Jan.	57,100	„	32·6
1 Feb.	45,400	„	26·0
	Bed rested 14 days		
8 Feb.	55,900	Lime effluent	32·0
1 Mar.	53,000	Screened sewage (3 fillings)	30·3
1 Apr.	45,000	39 grains per gal. suspended solids	25·7
27 Apr.	40,000	„	22·8
	Bed rested 7 days		
5 May	45,800	(2 fillings)	26·2
16 June	43,200	„	24·7
	Bed rested 38 days		
28 July	56,500	„	32·8
1 Sept.	42,000	„	24·0
	Bed dug over		
1 Oct.	46,500	Half-settled sewage (2 fillings)	26·6
1 Nov.	44,000	Say 20 grains per gal. suspended solids	25·1
	Bed rested 14 days		
1 Dec.	45,000	(3 fillings)	25·7
1899 1 Jan.	36,000	„	20·6
1 Feb.	31,800	„	18·2
1 Mar.	29,000	Resting on Sundays	16·6
1 Apr.	25,000	Crude sewage ditto (3 fillings)	14·3
6 May	22,700	Resting Wednesdays and Sundays	13·0
3 June	23,400	Resting alternate days (*i.e.*, 1½ fillings per day)	13·3
1 July	25,600	„	14·6
1 Aug.	26,800	(1 filling per day)	15·3
9 Sept.	27,300	„	15·6
7 Oct.	26,900	„	15·3

N.B.—The increase of capacity from 1st July, 1899, is more apparent than real, as with only 1 filling per day the bed would have a longer time to drain.

No. 3 Rough Contact Bed.

Capacity before putting in Coke - - - - Gals. 102,094
Original water capacity after putting in the Coke - - 51,800

Date	Gals.		Ratio per cent. of water capacity of total capacity.
1898 21 Nov.	51,800	Partially settled sewage (3 fillings)	50·7
5 Dec.	46,600	Rested on Sundays 35 grains per gallon suspended solids	45·6
1899 2 Jan.	38,100	„	37·3
1 Feb.	34,500	„	33·8
13 Feb.	30,400	Grit settled sewage (3 fillings)	29·7
1 Mar.	28,500	Rest on Sundays 39 grains per gallon suspended solids	27·9
27 Mar.	23,600	„	23·1
	Rested 18 days		
18 Apr.	28,600	„	28·0
2 May	21,700	„	21·2
	Surface removed	Beds rest alternate weeks	
31 May	24,900	„	24·4
28 June	22,500	„	22·0
1 Aug.	25,000	Resting alternate days (3 fillings)	24·5
1 Sept.	25,000	„	24·5
1 Oct.	24,500	„	24·0
1 Nov.	21,200	„	20·7
1 Dec.	21,700	„	21·2
1900 1 Jan.	18,000	„	17·6
10 Mar.	14,700	„	14·4
	Rested 16 days and surface cleared		
26 Mar.	21,200	„	20·7
1 Apr.	21,000	„	20·5
1 May	18,500	„	18·1
1 June	18,000	„	17·6
1 July	18,200	„	17·8
12 Oct.	12,900	„	12·6

No. 5 Rough Contact Bed.

Capacity before putting in coke - - - - Gals. 102,094
Original water capacity after putting in the coke - - 53,100

Date	Gals.		Ratio per cent. of water capacity of total capacity.
1899 28 Feb.	53,100	Grit settled sewage Rest on Sundays	52·0
14 Mar.	46,600	39 grains per gal. suspended solids	45·6
1 Apr.	42,000	„	41·1
9 May	32,500	(2 fillings per day) 4 hours contact	31·8
1 June	30,500	„	29·9
5 July	29,400	(2 fillings per day) 2 hours contact	28·8
2 Aug.	29,400	„	28·8
16 Aug.	29,900	(2 fillings per day) 4 hours contact	29·3
13 Sept.	28,300	„	27·7
	Rested 25 days		
24 Oct.	30,800	„	30·1
22 Nov.	25,400	„	24·9
1900 9 Mar.	27,600	(3 fillings per day) 2 hours contact	27·0
6 Apr.	23,000	„	22·5
4 May	18,100	„	17·7
1 June	13,200	„	12·9
	Rested 20 days surface cleaned		
22 June	20,500	„	20·1
20 July	16,600	„	16·2
17 Aug.	12,700		12·4
13 Sept.	9,300		9·1
	Bed cleaned		
25 Oct.	21,000		20·6
22 Nov.	14,900		14·6
20 Dec.	11,700		11·4

No. 7 Single Contact Bed.

Capacity before putting in coke - - - - Gals. —
Original water capacity after putting in the coke - - 55,700

Date	Gals.	
1899 24 Mar.	55,700	Lime effluent containing 10 grains per gallon suspended solids
21 Apr.		
	50,308	„
5 May	48,600	„
2 June	43,600	„
1 July	38,000	„
1 Aug.	33,000	„
1 Sept.	28,500	„
20 Oct.	21,600	„
	Bed rested and turned over	
1900 3 Jan.	53,500	„
2 Feb.	50,300	„
1 Mar.	46,000	„
1 Apr.	41,000	„
1 May	36,500	„
1 June	31,000	„
5 July	25,600	„
28 Sept.	20,700	
21 Dec.	17,500	

No. 8 Single Contact Bed.

Capacity before putting in coke - - - - Gals. —
Original water capacity after putting in the coke - - 29,500

Date	Gals.	
1899 23 May.	29,500	Septic tank effluent average 13 grains per gallon of suspended solids
6 Apr.	29,800	„
4 May	27,100	„
2 June	23,000	„
1 July	18,500	„
1 Aug.	16,000	
21 Sept.	10,700	
	Bed rested and turned over	
10 Nov.	26,900	
1 Dec.	24,500	
1900 1 Jan.	19,500	
1 Feb.	17,000	
1 Mar.	16,000	
1 Apr.	13,500	
4 May	12,200	
1 June	9,800	
1 July	11,000	
24 Aug.	9,700	
19 Oct.	9,500	
14 Dec.	10,500	

N.B.—Loss of capacity in Nos. 7 and 8 Beds was largely due to the consolidation of the material.

CONTACT. BEDS.

(61.) At what Rate or Rates do Primary Contact Beds and Secondary Contact Beds lose their Water-holding Capacity (*continued*).

p. 451 *Mr. E. G. Mawbey (Leicester):*

Water Capacities of Clarifying Bacteria Beds at Leicester (Primary Beds).

Total capacity of four clarifying bacteria beds = 19,978 cubic feet = 124,862 gallons.
Mean approximate area „ „ „ = 493 square yards.
Depth of „ „ „ = 4 feet 6 inches.

Sewage subjected to preliminary treatment in Detritus and Septic Tanks.

Date capacity measured.	Number of fillings.	No. of days since last measured.	Total water capacity of the four beds in gallons.	Percentages of increase or decrease in water capacity.	Percentages of water capacity compared with total capacity.	Volume treated per cube yard per day.	Volume per acre ($1\frac{1}{2}$ yards deep) of beds per day.	Remarks.
1898								
24 September -	3	—	61,865	—	49·54	250·83	1,822,068	
15 October -	3	21	59,066	4·52 decrease	47·305	239·48	1,739,631	
21 December -	3	67	49,795	15·69 „	39·88	201·89	1,466,577	
1899								
17 January -	3	27	45,052	9·52 „	36·08	182·66	1,326,885	
2 February -	3	16	44,459	1·31 „	35·60	180·26	1,309,419	
16 „ -	3	14	43,211	2·80 „	34·60	175·20	1,272,663	
3 March - -	3	15	45,432	5·14 increase	36·38	184·20	1,338,078	7th filling, after $3\frac{1}{2}$ days' rest.
15 „ - -	3	12	44,620	1·79 decrease	35·73	180·91	1,314,162	
29 „ - -	3	14	43,051	3·51 „	34·47	174·55	1,267,950	
10 April - -	3	12	48,238	12·04 increase	38·63	195·58	1,420,719	1st filling, after 10 days' rest.
13 „ - -	3	3	43,342	10·15 decrease	34·71	175·73	1,276,521	10th „ „ „
26 „ - -	3	13	42,896	1·02 „	34·35	173·92	1,263,387	
11 May - -	3	15	42,396	1·16 „	33·95	171·89	1,248,660	
17 „ - -	3	6	41,859	1·31 „	33·50	169·64	1,232,256	
30 „ - -	3	13	48,572	16·09 increase	38·90	196·93	1,430,556	1st filling, after 12 days' rest.
31 „ - -	3	1	45,178	6·98 decrease	36·18	183·17	1,330,596	4th „ „ „
14 June - -	3	14	42,563	5·78 „	34·06	172·57	1,253,577	
29 „ - -	3	15	41,839	1·69 „	33·50	169·64	1,232,256	
12 July - -	3	13	41,060	1·86 „	32·88	166·47	1,209,315	
27 „ - -	3	15	40,282	1·89 „	32·26	163·32	1,186,398	
10 August -	3	14	42,730	6·08 increase	34·22	173·25	1,258,497	4th filling, after $3\frac{1}{2}$ days' rest.
24 „ -	3	14	41,506	2·86 decrease	33·24	168·29	1,222,410	
7 September -	3	14	39,391	5·09 „	31·54	159·71	1,160,154	Heavy rain whole of 16 hours previous to test.
20 „ -	4	13	36,331	7·76 „	29·09	196·40	1,426,696	6th filling, after $3\frac{1}{2}$ days' rest.
4 October -	4	15	35,107	3·36 „	28·11	189·79	1,378,644	
6 November -	4	33	44,232	25·99 increase	35·42	239·12	1,736,976	1st filling, after 24 days' rest.
6 „ -	4	—	40,504	8·42 decrease	32·44	218·96	1,590,780	2nd „ „ „

(61.) At what Rate or Rates do Primary Contact Beds and Secondary Contact Beds lose their Water-holding Capacity (*continued*).

Fifth Report: Appendix I.

Messrs. Raymond Ross & Pickles (Burnley):

————	Capacity in Gallons.	Percentage capacity of empty tank.
First contact bed No. 5, made of washed and re-screened material. Contents: 3,081 cubic yards; 519,912 gallons.	—	—
June, 1904 (first filling) - - - - - - - - -	243,644	46·79
December, 1904 (6 months continuously, at 2 fillings per day) -	150,761	28·95
February, 1905 (bed having been allowed two rests amounting to 12 days) - - - - - - - - - - - -	151,669	29·13
First contact bed No. 18, made of unscreened furnace clinker. Commenced work January, 1898.		
June, 1899 - - - - - - - - - - -	108,255	25·6
September, 1900 - - - - - - - - - -	65,374	15·8
November, 1900 - - - - - - - - - -	69,800	16·8
October 1902 - - - - - - - - - -	61,300	14·7
March, 1905 - - - - - - - - - - -	56,786	13·7

40 A primary bed filled with washed and screened material would last seven years, perhaps longer. Secondary beds, probably twenty years A primary bed is still in use after seven years' working (20750).

4 Effluent treated contained 15 parts per 100,000 suspended matter (20959).

27 per cent. of empty water capacity is a fair average working capacity of contact beds.

Mr. Bolton (Heywood): (*a*) Primary beds.

At commencement - - - - - - -	49	per cent. capacity.
After 40 weeks (720 fillings) - - - - - -	32·2	,, ,,

(*b*) Secondary beds.

At commencement - - - - - - -	50	per cent. capacity.
After 40 weeks (720 fillings) - - - - - -	34·5	,, ,,

(*c*) Single contact treating chemically precipitated sewage

At commencement - - - - - - - -	32*	per cent. capacity.
After $4\frac{3}{4}$ years (3,972 fillings) - - - - - -	34·42	,, ,,
,, $6\frac{1}{4}$,, (6,392 ,,) - - - - -	31·9	,, ,,

* Rough measurement.

Analysis of Liquor (true Chemical Precipitated Sewage) Treated.

	Part per 100,000.
Oxygen absorbed, four hours' test - - - - -	3·38
Chlorine - - - - - - - - - - - -	6·7
Ammoniacal Nitrogen - - - - - - - - -	1·99
Albuminoid Nitrogen - - - - - - - - -	0·42
Nitric Nitrogen - - - - - - - - - -	Traces
Suspended Solids - - - - - - - -	4·0

CONTACT BEDS.

(61.) At what Rate or Rates do Primary Contact Beds and Secondary Contact Beds lose their Water-holding Capacity (*continued*).

21665 *Mr. Campbell* (*Huddersfield*): Beds lose capacity very rapidly at first, and then remain fairly constant for some time, the coarse bed at between 20 and 30 per cent. of original capacity, and fine bed at about 33 per cent.

———	Capacity in gallons.	Percentage capacity of Empty Tank.
(*a*) Coarse bed :		
August 1900	3,987	59 (initial capacity).
December 1901	1,670	25
„ 1902	1.610	24
January 1904	1,430	21
December 1904	1,026	16
(*b*) Fine beds :		
August 1900	3,900	59 (initial capacity).
November 1901	2,340	35
March 1903	2,200	33

Average Analysis (Parts per 100,000) of Liquor Treated on Beds.

———	Nitrogen from Free Ammonia.	Nitrogen from Albuminoid Ammonia.	Oxygen absorbed in 4 hours at 80° F.	Chlorine.	Suspended Solids.
Open septic tank	1·91	0·499	6·16	12·10	13·1
1st contact effluent	0·73	0·263	3·00	—	6·4
2nd contact effluent	0·18	0·156	1·53	12·00	—

22016 *Mr. Harrison* (*Leeds*): Typical figures showing loss of capacity in primary bed :—

Date.		Capacity with the 100 unit.	Actual galls.
1901	July 16	48·8	86,900
	September 27	44·4	79,100
	November 22	42·8	76,200
	December 20	44·4	79,100
1902	February 14	41·2	73,300
	April 11	39·5	70,300
	June 6	38·7	68,900
	August 29	37·9	67,400
	October 24	37·0	65,900
	December 19	37·0	65,900
1903	February 13	35·9	64,000
	April 9	34·8	62,000
	June 5	33·7	60,000
	August 1	33·7	60,000
	October 23	33·3	59,400
	December 18	31·6	56,200
1904	February 1	29·9	53,200
	April 8	29·1	51,800
	June 3	28·6	50,900
	August 26	27·1	48,100
	October 21	25·7	45,700
	December 16	22·7	40,500
1905	February 10	20·5	36,600

The bed was receiving two fillings per day of septic tank effluent and rested one week in every four. Average of analyses of liquor treated was as follows (parts per 100,000) :—

	Open Tank.	Closed Tank.
Ammoniacal Nitrogen	1·85	1·87
Albuminoid Nitrogen	·443	·418
Oxygen absorbed in 4 hours at 80° F.	6·10	5·48
Soluble Solids	89·4	88·1
Suspended Solids	19·4	16·0

Rate of loss of capacity is greater in winter than in summer.

(61.) AT WHAT RATE OR RATES DO PRIMARY CONTACT BEDS AND SECONDARY CONTACT BEDS LOSE THEIR WATER-HOLDING CAPACITY (*continued*).

22462 *Mr. Valentine* (*Oldham*): At Oldham, the capacity of the beds when first filled is 56 per cent. The loss of capacity in various beds is shown as follows :—

Time in use.	Capacity of bed
7 years	19 per cent
5½ „	19 „
5 „	20 „
4½ „	22½ „
3 „	29 „
2¼ „	30 „
1½ „	35 „
1¼ „	36 „
¾ „	41 „

23802 *Mr. Fowler* (*Manchester*): Experimental Beds A, B, C.

Empty capacity, about 10,000 gallons.

——	A 5th year.	B 5th and 6th year.	C 5th year.
	Capacity in Gallons.	Capacity in Gallons.	Capacity in Gallons.
May, 1903	2,350	2,600	2,200
December, 1903	2,320	2,640	2,260
March, 1904	2,140	2,370	2,060

Half-Acre Beds.

Initial Capacity, 200,000 gallons, or 44 per cent.

——	Capacity in Gallons.	Percentage of empty tank.
Bed No. 1A.		
June, 1903	132,320	29·1
October, 1903	128,800	28·3
December, 1904	96,480	21·0
Bed No. 1.		
November, 1903	126,300	27·8
June, 1904	99,220	21·8
Bed No. 8.		
January, 1904	167,340	36 8
September, 1904	108,140	23·7
Bed No. 2A.		
April, 1903	136,570	30·0
August, 1904	108,750	23·9
February, 1905	75,860	17·5
Bed No. 2.		
November, 1903	137,6[illegible]0	30·3
June, 1904	123,860	28·0
Bed No. 3.		
July, 1903	188,020	41·4
March, 1904	136,320	30·0
Bed No. 5.		
August, 1903	164,000	36·1
March, 1904	127,330	28·1

23115-8 The ultimate capacity at which the beds can be worked economically is 20 per cent. of empty capacity. Beds can be worked for certainly five years, and perhaps a year or two longer, before this capacity is reached.

CONTACT BEDS.

(61.) At what Rate or Rates do Primary Contact Beds and Secondary Contact Beds lose their Water-holding Capacity (*continued*).

Mr. Fowler (*continued*):

Average of Analyses of Septic Tank Effluent treated on Manchester Beds.

———	Parts per 100,000.
4 hours' oxygen absorption - - -	8·20
Ammoniacal Nitrogen - - - -	2·63
Albuminoid Nitrogen - - - -	·37

The average suspended matters amounted to 10·0 parts per 100,000, of which 5·7 were mineral.

23571 *Mr. Wike* (*Sheffield*): Typical Examples of Gaugings of a 1st Contact Bed.

———	Capacity in Gallons.	Percentage capacity of empty tank.
July, 1900 - - - - -	4,555	56·7
December, 1900 - - - -	2,778	34·6
„ 1901 - - - -	2,180	27·1
1902 - - - -	2,013	25·0
„ 1903 - - - -	1,518	18.9
After turning material	completely over.	
February, 1904 - - - -	2,088	26·0
December, 1904 - - - -	1,971	24·5
April, 1905 - - - - -	1,712	21·3

Typical Examples of Gaugings of a 2nd Contact Bed.

———	Capacity in Gallons.	Percentage capacity of empty tank.
August, 1900 - - - - -	4,320	54·1
December, 1900 - - - -	4,021	45·1
„ 1901 - - - -	3,408	38·2
March 11th, 1902 - - - -	3,344	37·5
„ 18th, 1902 - - - -	3,611	40·5*
December, 1902 - - - -	3,277	36·2
„ 1903 - - - -	3,118	35·0
„ 1904 - - - -	2,790	31·3
April, 1905 - - - - -	2,627	29·5

* Material having been completely turned over.

26089 *Messrs. Willcox & Raikes*: Experimental contact beds at Hanley working at rate of about four fillings a day for two years have become clogged.

(62.) ON WHAT DOES THE LOSS OF CAPACITY IN CONTACT BEDS DEPEND.

Interim Report: Vol. II. (Cd. 686) 1902.

2134–7 *Mr. D. Cameron*: Reduction of capacity undoubtedly due to consolidation of material and formation of soil (caused by suspended solids in tank effluent) on immediate surface. Thinks it probable that there is also formation on material below surface.

3964–7 *Mr. Dibdin*: Suggests that reduction is caused principally by retention of water in the material (refers especially to coke).

7 63 *Col. Harding*: Loss of capacity apparently due to following causes:—

(1) Admission of sand, coal dust, and road detritus into bed.
(2) Degradation of material.
(3) Consolidation of material.
(4) Excessive amount of organic solids passed on to bed.
(5) Presence in sewage of matters (other than sand and road detritus) which cannot be reduced by bacterial action.
(6) Retention in bed of mineral solids originally in solution, but which are brought into suspension by oxidising action of bed.

Fifth Report: Appendix I.

20784 *Messrs. Raymond Ross & Pickles (Burnley)*:

(*a*) Formation of gelatinous matter on surface and in material of bed.
(*b*) Non-destructible suspended matter carried into bed.
(*c*) Disintegration and consolidation of material (accounts almost entirely for further loss of capacity after bed has once matured).
(*d*) Accumulation of irreducible humus.

20978–9 The use of fine material which will not disintegrate is of great importance.

21156 *Mr. Bolton (Heywood)*:

(*a*) Beds treating precipitated sewage. Loss of capacity due to gelatinous growth. Restored by resting.
(*b*) Beds treating septic tank liquor. Loss of capacity due to solid matter passed on to bed.

21171 *Mr. Kershaw (Rotherham)*: The loss of capacity is in proportion to the volume of liquid treated and the amount of suspended matter it contains. Proportion of inorganic matter in suspended matter is also of importance, and the grade of the material.

(62.) ON WHAT DOES THE LOSS OF CAPACITY IN CONTACT BEDS DEPEND (*continued*).

21666 *Mr. Campbell* (*Huddersfield*): Varies directly with the amount treated, and also with the suspended solids, but not in any fixed proportions. Fineness or coarseness of material makes a difference, and loss is also due to degradation and consolidation of material.

22016 *Mr. Harrison* (*Leeds*): The rate of loss of capacity is—

(*a*) In proportion to the amount of suspended solids in liquor treated.

(*b*) In inverse ratio to the amount of rest given.

(The above is a general statement and is not intended as numerically accurate. 22155–9.)

(*c*) Is greater in winter than in summer.

The loss of capacity is due to—

(1) Admission of indigestible matters into the body of the filter.

(2) Breaking down of the bed material.

(3) Consolidation of the bed material.

(4) Formation of a form of organic earthy matter akin to humus in body of filter.

(5) Large amount of water retained in spongy deposit round material.

22463 *Mr. Valentine* (*Oldham*): Difficult to say. Suggests two factors as important, viz., the deposition of very fine suspended matter in solution, and the disintegration and settlement of the material.

22656 *Dr. Wilkinson* (*Oldham*): The loss of capacity is in direct proportion to—

(*a*) The volume treated and the amount of suspended solids.

(*b*) The fineness of the filtering material.

(*c*) The liability of the material to disintegration; insufficient draining of the bed also causes clogging.

22688 Disintegration of material is an important factor.

22803 *Mr. Fowler* (*Manchester*)

(*a*) Settling together of material.

(*b*) Growth of organisms.

(*c*) Impaired drainage.

(*d*) Insoluble matter entering bed.

(*e*) Breaking down of material.

23572 *Mr. Wike* (*Sheffield*): Amount of suspended solids is an important factor; but there are other considerations (not specified).

Net loss in capacity does not seem to be in direct proportion to volume treated.

(62.) On what does the Loss of Capacity in Contact Beds depend (*continued*)

23016 *Mr Haworth* (*Sheffield*): In addition to purely mechanical causes, and the effect of undigested solids, the growth of the gelatinous coating on surface of bed contributes to reduce capacity.

24292 *Mr. Wilkinson* (*Manchester*): The volume treated, the amount of suspended solids, and the grade of material are factors of importance.

26089 *Messrs. Willcox & Raikes*: Loss of capacity depends on quantity of suspended or colloidal matter in tank liquor and on size of filtering media. Suspended matter will pass through with filtrate if bed s filled with large sized material.

CONTACT BEDS.

(63.) HOW CAN THE CAPACITY OF CONTACT BEDS BE BEST MAINTAINED.

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1798–9 *Mr. Santo Crimp:* If choking due to organic matter, resting would suffice.

2086 *Mr. D. Cameron (Exeter):* Attaches importance to thoroughly draining beds.

3813–9 (3982 *Mr. Dibdin:* Sufficient periods of rest for restoring capacity; and it is advantageous to keep out road detritus, coal washings, and the like.

7063 *Col. Harding:* Important to exclude sand, coal dust, and road detritus, and also fibre and certain vegetable matters. Material should be of very even size to prevent consolidation as far as possible.

7064* Capacity of beds at Leeds was maintained to a certain extent by frequent rests, and reduction of work.

Fifth Report: Appendix I.

20786 20978–9 *Messrs. Raymond Ross & Pickles (Burnley):*

(1) By efficient drainage.
(2) By use of fine material which will not disintegrate.
(3) By filling beds quietly and evenly, and keeping out suspended matter as far as possible.
(4) By allowing periods of rest.
(5) By keeping surface in good order.

21028 Also by removing the material, screening, washing it, and putting it back.

21157* *Mr. Bolton (Heywood):* By regular periods of rest, and by placing layer of fine material on surface to be replaced as it gets choked.

21473 *Mr Kershaw (Rotherham):*

(1) By keeping down amount of suspended solids.
(2) By not overworking.
(3) By thorough draining off.
(4) Complete rest as often as possible.
(5) Forking over or loosening of surface should be done carefully, so as not to disintegrate material.

(63.) How can the Capacity of Contact Beds be best Maintained (*continued*).

CONTACT BEDS.

21668 *Mr. Campbell* (*Huddersfield*) :

(1) By keeping down amount of suspended solids in liquid.
(2) By use of fine layer of material on surface which can be removed and renewed
(3) Use of material which will not readily disintegrate.
(4) Frequent resting.

22022 *Mr. Harrison* (*Leeds*) : By removing suspended matter from liquid going in to bed. Good results have also been obtained at Leeds by covering bed with layer of very fine coke breeze to a depth of six inches. Experience shows, however, that sooner or later material must be washed or renewed.

22465 *Mr. Valentine* (*Oldham*) : Use of hard vitrified material would prevent any loss through disintegration; but can suggest no means of maintaining the capacity of the bed to a reasonable degree.

22805 *Mr. Fowler* (*Manchester*) :

(*a*) Bed should be worked very slowly at first for settlement and formation of bacterial growth.
(*b*) Bed should not be worked fully until analysis shows the presence of surplus oxygen.
(*c*) When capacity is found to be rapidly decreasing, a period of rest should be given.
(*d*) Long periods of rest should be avoided in winter. Without the heat of sewage, activity of organisms decreases.
(*e*) Insoluble suspended matter should be retained on surface by layer of fine material not more than 3 inches deep.

23574 *Mr. Wike* (*Sheffield*)

(1) Interception of suspended solids as far as possible.
(2) Lining of distributing channels with fine material, and frequent cleansing of channels.
(3) Period of rest given to bed when capacity falls off.

236176 *Mr. Haworth* (*Sheffield*) : By watching analytical results carefully, so that proper periods of rest can be given.

24294 *Mr. Wilkinson* (*Manchester*) :

(*a*) By allowing ample area, especially in primary beds.
(*b*) By reducing suspended solids in tank liquor to a minimum.
(*c*) By maintaining a fairly fine surface and giving constant attention to removal of deposited matter from surface.
(*d*) By regularity in resting periods.

26092 *Messrs. Willcox & Raikes* : By selecting material that will not disintegrate and working beds at a uniform rate not exceeding two fillings a day.

CONTACT BEDS.

(64.) CAN THE MATERIAL OF A CLOGGED BED BE WASHED, AND, IF SO, HOW, AND AT WHAT COST PER CUBIC YARD.

Fifth Report: Appendix I.

20785 *Messrs. Raymond Ross & Pickles (Burnley)*: Yes, without difficulty, by means of a rotary screen. Apart from capital outlay (£280 at Burnley), the whole cost at Burnley was at the rate of 1s. per cubic yard.

Washed material is far better than new material (21023). Twelve months' experience of washed bed (21024).

21017–20 Cost of renewing material of bed probably about 4s. per cubic yard.

21157 *Mr. Bolton (Heywood)*: Yes, by passing material through revolving screen with a supply of water. Thinks that this would cost 2s. per cubic yard, but apparently has had no personal experience of this method of washing.

21472 *Mr. Kershaw (Rotherham)*: No experience; but thinks washing possible.

21667 *Mr. Campbell (Huddersfield)*: Yes, but cost is prohibitive. Finds that the cost of washing is 4s. 6d. per cubic yard (21852).

22017 *Mr. Harrison (Leeds)*: Has washed 1,020 cubic yards by hand labour at a cost of 2s. 5d. per cubic yard. With mechanical apparatus, cost should be very considerably reduced.

22684–7 *Dr. Wilkinson (Oldham)*: Thinks it practicable; but has had no experienc

22804
23120–5 *Mr. Fowler (Manchester)*: Yes, easily, by means of an elevator working in a sump through which effluent runs and into which the clogged material is tipped. This is done at Burnley at cost of 1s. per cubic yard, exclusive of capital cost of plant.

23573 *Mr. Wike (Sheffield)*: Only had slight experience of washing and that by hand. Washing on a large scale could probably be carried out within practicable limit of cost.

(64.) Can the Material of a Clogged Bed be Washed, and, if so, how, and at what Cost per Cubic Yard (*continued*).

Messrs. Willcox & Raikes: Yes, by means of a water jet working with a good pressure. Fine material may require to be removed for washing. Cost of removing, washing and replacing should not exceed 1s. per cubic yard exclusive of cost of water, for which, however, filtered effluent might be substituted. (*See also* 26319–21.)

CONTACT BEDS.

(65.) COST OF CONTACT BED INSTALLATION PER ACRE, AND AMOUNT OF LIQUID TREATED PER ACRE PER TWENTY-FOUR HOURS IN ORDINARY TIMES AND IN STORM TIMES.

Interim Report: Vol. II. (Cd. 686) 1902.

2183 *Dibdin:* First contact bed at Sutton was merely a hollow in the natural ground, drained and filled with coke, etc. The area was one-tenth of an acre, depth 3 feet, and cost less than £100. The cost of corresponding fine bed was estimated at £120, total £220. This gives a rate of £2,200 per acre for double contact.

If beds were increased to 5 feet in depth, estimated cost would be £3,400 per acre (double contact).

Another bed at Sutton was constructed by Surveyor at cost of £726 per acre.

The 3-feet beds above referred to are capable of treating 77,300 gallons per day or at the rate of 773,000 gallons per acre per day.

Fifth Report: Appendix I.

20795 *Messrs. Raymond Ross & Pickles (Burnley):* £1,300 per acre. Amount treated by double contact on beds 3 feet deep is 217,800 gallons per acre per day.

21165 *Mr. Bolton (Heywood):* Single contact beds: Cost works out at £21,240 per acre; but only 1,340 sq. yards
21221 are constructed, and this is of very elaborate and unnecessarily costly construction.

Tank liquor treated at rate of 822,800 gallons per acre per day.
Storm sewage not more than 1,097,000 gallons per acre per day.
Depth: 3 feet.

21674 *Mr. Campbell (Huddersfield):* £1,700 per acre.

	acres
Area required to treat 1,000,000 gallons in ordinary times - - - -	2·20
„ „ „ „ storm „ - - - -	1

(On the basis of double contact with beds 3½ feet deep.)

224746
22663 *Mr. Valentine and Dr. Wilkinson (Oldham):* The beds have worked at the rate of about 350,000 gallons per acre per twenty-four hours during the years 1903 and 1904. Beds rarely filled more than twice a day.

The cost of the beds was from £1,000 to £2,000 per acre.

The system is single contact, and average depth of beds is 3 feet.

22814 *Mr. Fowler and Mr. Wilkinson (Manchester):* Cost of beds, £2,650 per acre.

24295 Amount treated: About 400,000 gallons per acre ordinarily; as much as 1,000,000 gallons in very wet weather.

Single contact: depth of beds, 3 feet 4 inches.

(65.) Cost of Contact Bed Installation per Acre, and Amount of Liquid treated per Acre per Twenty-four Hours in Ordinary Times and in Storm Times (*continued*).

9 *Mr. Wike* (*Sheffield*): About £4,460 per acre. (Estimate of cost of new beds.)

1 *Messrs. Willcox & Raikes*: Experimental contact beds at Hanley cost about £4,500 per acre; were 3 feet deep and were worked at a uniform rate of four fillings per day, double contact. The amount treated was at the rate of 225 gallons per cubic yard per day in each bed, which equals $112\frac{1}{2}$ gallons per cubic yard calculated on the capacity of the two beds together. (£4,500 per acre not to be regarded as representative of the usual cost of contact beds; a cheaper form of construction was adopted for the Hanley experimental beds than would ordinarily be the case for permanent beds (26184).)

(66.) TO WHAT EXTENT IS THE ORGANIC MATTER OF THE SUSPENDED SOLIDS IN A CONTACT BED EFFLUENT DIFFERENT FROM THE ORGANIC MATTER OF THE SUSPENDED SOLIDS GOING INTO THE BED.

Fifth Report: Appendix I.

21161 *Mr. Bolton (Heywood)*: Solids leaving bed are granular and settle quickly: solids going in do not settle rapidly, are more gelatinous in appearance, and keep in suspension.

21671 *Mr. Campbell (Huddersfield)*: Solids coming out of the bed are usually non-putrescible.

22470 *Mr. Valentine (Oldham)*: No data as to chemical difference; but there is a distinct difference in physical characteristics. Suspended matter from tank is flocculent and coarse, generally black, and of a putrescent nature: that from filter is very fine and generally not putrescible.

22810 *Mr. Fowler (Manchester)*: More granular and less colloidal: contains much organic life. (Further investigation needed).

23620 *Mr. Haworth (Sheffield)*: No analysis made, but solids are usually less putrescible and frequently at Sheffield consist largely of iron hydroxide.

26097 *Messrs. Willcox & Raikes*: Analyses show that the chemical composition of the suspended solids entering and leaving the beds is practically the same.

(67.) IS THE FIRST FLUSH OF EFFLUENT FROM EITHER SET OF CONTACT BEDS EVER PUTRESCIBLE. CONTACT BEDS.

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5–6 *Col. Harding* : First flush from second contact beds would always contain putrescible solids.

Fifth Report : Appendix I.

92 *Messrs. Raymond Ross & Pickles* (*Burnley*) : From primary beds, generally putrescible ; from secondary beds, practically never putrescible.

162 *Mr. Bolton* (*Heywood*) : Yes.

671* *Mr. Campbell* (*Huddersfield*) : From primary beds, probably always putrescible ; from secondary beds, generally non-putrescible.

471 *Mr. Valentine* (*Oldham*) : Yes; this is generally the case, especially where strong tank effluents are treated.

661 *Dr. Wilkinson* (*Oldham*) : Yes.

811 *Mr. Fowler* (*Manchester*) : Yes.

576 *Mr. Wike* (*Sheffield*) : Slightly putrescible at times from first beds.

(67.) Is the First Flush of Effluent from either Set of Contact Beds ever Putrescible (*continued.*)

23921 *Mr. Haworth (Sheffield)*: From primary beds, putrescible at times, but not from secondary beds.

26108 *Messrs. Willcox & Raikes*: Always putrescible from first beds and frequently from second.

(68.) WHAT IS THE ACTION OF CONTACT BEDS WHEN FULL AND WHEN RESTING.

CONTACT BEDS.

Interim Report : Vol. II. (Cd. 686) 1902.

age 119. (See also 902-5.) *Mr. Dibdin* : In empty bed, "the undestroyed portion of organic matter is vigorously attacked by the organisms under the most favourable circumstances of combined dampness and air supply, and the bed is thus prepared for a further change."

133 (p. 246.) *Dr. Rideal* : During "resting full" periods, changes are really anaerobic : during emptying and resting empty periods, the aerobic bacteria are at work.

207-8 Nitrates present in effluent from Exeter bed were formed during the periods of rest.

Fifth Report : Appendix I.

1166 *Mr. Bolton (Heywood)* : Gives following average analyses—

	Tank liquor.	Continuous flow after filter has been run off.	Continuous flow after filter has had period of rest.
Oxygen absorbed (4 hours test) -	2·00	1·31	0·87
Ammoniacal Nitrogen - - -	2·29	1·95	1·15
Albuminoid Nitrogen - - -	·42	·28	·26
Nitric Nitrogen - - - -	Nil.	Traces	·77

2021 *Mr. Harrison (Leeds)* : Generally speaking, the solids left in the bed are oxidised when bed is resting empty, liquid impurities are oxidised when the bed is full. This is inferred from the general facts gathered (22164).

2475 *Mr. Valentine (Oldham)* : Comparative analyses show that oxidation and nitrification more readily take place near the top than near the bottom. Best condition for working, having regard to purification, is to have liquid showing through uppermost layer of material.

2815 *Mr. Fowler (Manchester)* :

(1) Long contacts with new beds show that much impurity may be removed simply by physical effect of contact.

(2) Absorption of oxygen and proportion of carbon di-oxide by gelly-like humus from beds shows active oxidation during rest.

(3) Nitrates are formed during rest and are partly used up in oxidising organic matter during period of standing full.

CONTACT BEDS.

(68.) WHAT IS THE ACTION OF CONTACT BEDS WHEN FULL AND WHEN RESTING (*continued*).

26102 *Messrs. Willcox & Raikes*: Apparently very little purification takes place after air is expelled by inflowing sewage, most of purification taking place during process of filling. During period of rest, solid matter in bed is decomposed.

(69.) WHAT ARE THE CONDITIONS OF AERATION OF CONTACT BEDS. CONTACT BEDS.

Fifth Report: Appendix I.

0797 *Messrs. Raymond Ross & Pickles* (*Burnley*): Only get satisfactory results when distribution is good and moderate periods of rest are allowed for aeration.

22476 *Mr. Valentine* (*Oldham*): Best results obtained by affording all possible means of access of air. Has found that vertical vent. pipes at the upper ends of the drains at bottom of bed aids aeration. Valves should be fully opened during period of rest.

22816 *Mr. Fowler* (*Manchester*): Has never found any serious deficiency of oxygen except when bed was overworked. Bed recovered rapidly on resting.

26103 *Messrs. Willcox & Raikes*: When bed is emptied the interstices are charged with air, but no circulation can be observed during period of rest.

CONTACT BEDS.

(70.) IS THERE ANY NUISANCE FROM THE TREATMENT OF SEWAGE ON CONTACT BEDS.

Fifth Report: Appendix I.

20798 *Messrs. Raymond Ross & Pickles (Burnley)*: No.

21168 *Mr. Bolton (Heywood)*: No.

21484 *Mr. Kershaw (Rotherham)*: No.

21677 *Mr. Campbell (Huddersfield)*: No.

22477 *Mr. Valentine (Oldham)*: No.

22664 *Dr. Wilkinson (Oldham)*: No.

22817 *Mr. Fowler (Manchester)*: No.

23580 *Mr. Wike (Sheffield)*: No.

26104 *Messrs. Willcox & Raikes*: No.

(71.) WHAT ARE THE BEST FILTERING MATERIALS FOR PERCOLATING FILTERS, AND WHAT SIZE SHOULD THE MATERIAL BE.

Interim Report: Vol. II. (*Cd.* 686) 1902.

2180 *Col. Ducat*: Very hard vitrified cinders or clinker, or clean pebbles or other clean rough material of suitable size that will form a good nidus for microbes and will not readily disintegrate. Has tried both cinders and pebbles with good results (2231–3).

Size: about $\frac{1}{2}$ to $\frac{1}{4}$ inch for upper part of filter, and about $\frac{1}{8}$ inch for bulk of it, with material about 1 inch in size for drainage layer at bottom. Made large number of experiments with different size material from 3 inches downwards (2304–6).

3408 *Mr. Garfield* (*Wolverhampton*): As a result of large number of experiments with different materials, finds that coal is the best filtering medium.

3411 Size: $\frac{1}{16}$ inch cubes for top layer; $\frac{1}{8}$ inch cubes for remainder.

4030-2 *Dr. Barwise*: Experiments with filters constructed of coal, coke, and destructor breeze, respectively, show that coal gave best results. Filters had been working about eighteen months.

Size: Coal used was hard and was $\frac{1}{8}$ inch to $\frac{1}{16}$ inch in size. Soft coal should be larger.

4365 *Mr. C. J. Whittaker* (*Accrington*): Size is the important thing, not the nature of the material. It should be about $1\frac{1}{2}$ inches to 2 inches in size. Coke was found to give the best size.

7001-2 *Mr. F. Candy*: Claims that polarite is the best filtering material, owing to its being porous in every direction.

7373-4 *Col. Harding*: In dealing with Leeds crude sewage, best results were obtained by using very coarse material (coke).

7865-71 *Alderman Hibbert* (*Chorley*): Chorley filters are made of polarite and sand. Has experimented with coke breeze, coke, and gravel, and finds that the polarite filters give the best results.

7879-81 Polarite approximates in size to a $\frac{1}{4}$ inch cube. Mechanical action of filter depends on size of material.

7946* No disintegration in the polarite.

PERCO-LATING FILTERS.

(71.) WHAT ARE THE BEST FILTERING MATERIALS FOR PERCOLATING FILTERS, AND WHAT SIZE SHOULD THE MATERIAL BE (*continued*).

Fifth Report: Appendix I.

21168 *Mr. Bolton (Heywood)*: Well-burned destructor and furnace clinker of size from 4 inches to 2 inches.

21678 *Mr. Campbell (Huddersfield)*: A good hard clinker which will expose a good filtering surface. The material should be fairly coarse, say, material rejected by $1\frac{1}{2}$ inch mesh.

22023 *Mr. Harrison (Leeds)*: Coke, broken bricks, or any material which is not liable to disintegration. Material of not less than 3 inches in diameter is a useful size. The solids should be able to pass through gradually and appear in the filtrate.

22302 A percolating filter of coarse material not readily liable to degradation will work for almost an indefinite period.

22794
22818 *Mr. Fowler (Manchester)*: Hard furnace clinker found to be the best material at Manchester. Broken Staffordshire bricks, broken "saggers," gravel, and the like, should do equally well. Vitally important in a percolating filter that there shall be no breaking down of the material with consequent formation of inequalities in the distribution; for the same reason all fine dust must be carefully removed.

22819 Experiments at Manchester extending over several years showed that with the same liquid, purification increases directly with the fineness of the material. The following Table gives comparative analytical figures:

PERCOLATING FILTERS dealing with Manchester Open Septic Tank Effluent.

Analytical Results.

Showing effect of size of material on filtrate obtained:

1. Material anything above 3–16 inches. Very little coarse.
2. Material passed through 2-inch mesh and rejected $\frac{1}{2}$-inch mesh.
3. Material larger than 2inches.

——	1.	2.	3.
4 Hours' Test	2·70	3·80	4·63
Ammoniacal Nitrogen	1·69	2·41	2·98
Albuminoid Nitrogen	·15	·21	·22
Nitrous Nitrogen	·06	·05	·02
Nitric Nitrogen	·83	·18	·07
3 Minutes' Oxygen Test	1·36	2·36	2·53
3 Minutes' Oxygen Test (after incubation)	1·19	2·86	3·29
Putrescibility	$2\frac{1}{2}$/73	$26\frac{1}{2}$/40	35/38
Chlorine	—	—	18·6
Average amount dealt with per cubic yard per day.	130 gallons.	94 gallons.	75 gallons.
Depth of filter	3 feet.	3 feet.	6 feet.

23236 *Mr. Carter Bell (Salford)*: Clinkers, $\frac{3}{16}$th to $\frac{3}{4}$ inch. (Has tried various materials: 23328.)

(71.) What are the best Filtering Materials for Percolating Filters, and what Size should the Material be (*continued*). PERCO-LATING FILTERS

24432 (p, 576) *Dr. Reid*: Any hard non-friable material of irregular shape and not too smooth and not liable to disintegrate is suitable. Instances gravel, shingle, granite, blue bricks, saggers, clinker, coke, coal. Finds that most effective size is $\frac{1}{8}$ inch to $\frac{1}{4}$ inch, but it is more economical to provide larger particles ($\frac{1}{4}$ inch to $\frac{1}{2}$ inch) for body of filter, the top layer to a depth of 9 inches to 12 inches only being formed of the smaller particles.

24526–71 Important to have fine material on top. This arrests suspended matter which is digested in the top layer. Instances Burslem, where 32 parts per 100,000 are sent on to filter, yet only one part comes out in filtrate. There is no choking of the filter, or any appreciable accumulation on surface. Filter been working five years.

See also 27075 as to experiments at Hanley

25004 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): In order of merit—granite, broken bricks, selected slag, gravel, furnace clinker.

Hardness is the essential qualification (25418–9).

Most suitable size can only be determined after prolonged and exhaustive tests.

Suggest as follows:—Top 9–12 inches—$\frac{3}{4}$-inch to $1\frac{1}{4}$-inch cubes.
Next 12 inches—$\frac{1}{2}$ inch cubes.
Remainder of depth—2-inch to 3-inch cubes.

25348 Advantage to make filters coarse enough to allow undigestible matter to pass through.

25776–7 *Mr. F. Scudder*: Material must not be fine. Filter must be so constructed that suspended matter not liquefied or changed into gaseous form will pass out with effluent. Fine material also is apt to result in a slimy growth which gets well down into the filter (25782–4).

26105 *Messrs. Willcox & Raikes*: Best material is crushed saggers, and for this material the most suitable size is from $\frac{1}{4}$ inch to $\frac{1}{2}$ inch. Good results also obtained with clinker, gravel, granite, slag, and blue brick. Best size for different materials varies considerably, the object being to regulate the size of the interstices rather than the lumps of material itself (26184).

26178 Important to use local material wherever possible, owing to heavy cost of carriage.

PERCO-
LATING
FILTERS

(72.) WHAT DEPTH SHOULD A PERCOLATING FILTER BE.

Interim Report: Vol. II. (Cd. 686), 1902.

2187 *Col. Ducat*: Depth may vary according to nature of sewage and amount of purity required.

Depth of 5 feet would suffice where filtrate is discharged into tidal waters; 8 feet would be sufficient for inland rivers; but 10 feet or more should be given if filtrate is to go into small drinking water stream. No experiments to prove this; it is only a pious opinion (2335–7).

3411 *J. Garfield (Wolverhampton)*: Depth should be 5 feet where possible. (Refers to coal filters.)

4925 *Mr. C. J. Whittaker (Accrington)*: Principal action takes place in upper 3 feet of material; but it is necessary to have extra depth to balance irregularities in filter. Accrington filters are 9 feet deep.

Fifth Report: Appendix I.

21169 *Mr. Bolton (Heywood)*: Has tried 3-feet and 8-feet beds. The former sufficient for weak tank liquors (under 3 parts per 100,000 in the four hours' oxygen absorbed test and under ·2 parts per 100,000 albuminoid nitrogen.)

8-feet bed always gave satisfactory filtrate (*i.e.*, within Mersey and Irwell standard).

21679 *Mr. Campbell (Huddersfield)*: Experimental bed at Huddersfield is 7 feet deep, and usually gives about 90 per cent. purification.

22024 *Mr. Harrison (Leeds)*: Depth should vary according to amount of solids in liquor, *e.g.*—

(*a*) With screened sewage containing an average of 57 parts of suspended matter - - - - - - - - - - - - - - 10 to 12 feet deep.
(*b*) With septic tank liquor or settled sewage containing about 15 to 17 parts of suspended matter - - - - - - - - - 8 to 10 feet deep.
(*c*) Liquid containing a small proportion of suspended matter such as well precipitated sewage - - - - - - - - - - 5 to 6 feet deep.

22373–9 (The above view founded on actual experiments with sewage containing varying amounts of solids: 22169.)

Shallower filters may be used if suspended matters are further reduced, or perhaps if rate of flow is reduced.

Does not think crude sewage could be successfully treated with much under 7 or 8 feet depth, even with a very reduced flow.

(72.) What Depth should a Percolating Filter be (*continued*). PERCO-LATING FILTERS.

23237 *Mr. Carter Bell* (*Salford*): 5 feet.

23330–1 Comparative experiments with 5-feet and 8-feet filters showed that the deeper filter gave a better filtrate on the average; but he does not think the result warrants the extra expense.

23406 Broadly speaking, at the same rate of flow, better results are obtained from a deeper bed. Has experimented with beds from 1 to 5 feet deep.

15522–3 (Third Report: Vol. II.) A 3 feet 6 inch filter did not give sufficient purification to warrant its adoption.

24432 (p. 576) *Dr. Reid*: Efficient depth is 5 feet, for ordinary sewage. This depth would probably not suffice, however,
24646 for brewery sewage or for sewage containing large amount of tannery waste. Not desirable to have filters exceeding 5 or 6 feet in depth. Better to provide two shallow filters than one deep bed, if
27075 *et seq.* unusually prolonged filtration is necessary. See, however, later evidence at 27075 as to experiments at Hanley, which tend to show that where fine material ($\frac{1}{8}$ inch) is used the great bulk of the work is done by the top foot of the filter. Thinks it practicable to reduce depth of filter to 2 feet 6 inches.

25005
25389 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): Minimum depth, 5 feet: 6 feet depth preferable. A secondary filter should be deeper than primary filter.

26106 *Messrs. Willcox & Raikes*: Exellent results obtained at Hanley with filters 5 feet deep preceded by septic tank. Samples of effluent taken at depth of 14 inches from surfaces showed purification of 90 per cent. as measured by albuminoid ammonia, and 89 per cent. by oxygen absorbed. These good results are largely attributed to efficient distribution (26184). Samples of effluent were taken at depths of 1 foot, 2 feet and 3 feet and it was found that very little purification remained to be done after first foot. This conclusion is based on a large number of observations (26189–26201).

Generally the most efficient depth for filters must be determined experimentally for each case.

(73.) IS IT GENERALLY DESIRABLE THAT SEWAGE SHOULD BE SUBJECTED TO SOME FORM OF TANK TREATMENT BEFORE IT IS PUT ON PERCOLATING FILTERS.

Interim Report: Vol. II. (Cd. 686) 1902.

1671-3 *Mr. Santo Crimp*: Preliminary settlement desirable (result of twenty years' experience).

3411 *Mr. J. Garfield*: With coal filters there must be some preliminary process for removal of suspended solids.

5752 *Mr. C. J. Whittaker*: From experience at Morley considers that fresh sewage cannot be treated by these
5754-5 filters; tank treatment necessary.

5019 *Mr. F. W. Stoddart*: Yes.

7396 *Colonel Harding*: Thinks it practicable, with a very coarse filter, such as the one at Leeds, that Leeds crude sewage can be dealt with without any antecedent treatment but screening.

7461 In the case of domestic sewage, preliminary tank treatment would seem to be necessary.

7518-20 *Mr. G. R. Strachan*: Preliminary removal of solids is desirable, though not essential.

Third Report: Vol. II. (Cd. 1487) 1903.

15466 *Mr. J. Corbett (Salford)*: Efficient precipitation in tanks is a first essential. Roughing filters are also of importance.

(73.) Is it generally desirable that Sewage should be subjected to some form of Tank Treatment before it is put on Percolating Filters (*continued*).

Fifth Report: Appendix I.

170 *Mr. Bolton (Heywood)*: Yes.

680 *Mr. Campbell (Huddersfield)*: Yes.

025 *Mr. Harrison (Leeds)*: Yes, suspended matter should be removed as far as possible, as a clarified liquor can be more easily and rapidly treated, and the absence of suspended matter in the filtrate obviates the necessity for further treatment.

820 *Mr. Fowler (Manchester)*: In certain cases, if very efficient screening is resorted to, tank treatment may be dispensed with. A corresponding greater provision must, however, be made at the outlet, and coarse material must be used.

238 *Mr. Carter Bell (Salford)*: Yes.

581 *Mr. Wike (Sheffield)*: Yes.

32 (p. 576) *Dr. Reid*: Not absolutely necessary, if the sewage is passed through detritus tanks. Gives illustration of successful working of percolating filters (double filtration), after mere screening and subsidence of detritus.

06 *Messrs. Watson & O'Shaughnessy (Birmingham)*: Yes; but preliminary treatment need not be carried far, as in any case the filtrate will contain suspended solids which must be removed by some subsequent process (25361–5).

792–4 *Mr. F. Scudder*: Desirable to thoroughly clarify the effluent before putting it on the filter, notwithstanding that a further process for removing the suspended matters in the filtrate will be necessary in any case.

107 *Messrs. Willcox & Raikes*: Preliminary tank treatment is essential with fine grade filters.

PERCO-
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(74.) IS THE MATERIAL IN PERCOLATING FILTERS BETTER DISPOSED IN THE FORM OF TWO BEDS, TO BE FED IN SUCCESSION, OR IN ONE DEEP BED.

Interim Report: Vol. II. (Cd. 686) 1902.

993 *Dr Sims Woodhead*: The system of Mr. Scott Moncrieff (succession of trays or filters) goes to show that the filtrate is improved with each filter.

2404-6 *Mr. Scott Moncrieff*: Considers that a number of trays fed successively result in more efficient purification. The larger the number of trays the better the purification.

4252 *Dr. Rideal*: From the comparative results submitted, witness argues that nitrification is more complete in the Scott Moncrieff filter than in other forms.

7381 *Colonel Harding*: Better results were obtained from a single deep bed, than from practically the same amount of material disposed in the form of three beds. A triple system was open to objection on account of the necessity for separate distributors which resulted in the cooling of the sewage (7378).

Fifth Report: Appendix I.

21170* *Mr. Bolton (Heywood)*: Better disposed in one bed. Tried two beds fed in succession, and found that the second bed quickly choked up from the humus matter from first bed.

21681 *Mr. Campbell (Huddersfield)*: One deep bed, an acre in extent, is required for large works

23209 *Mr. Carter Bell (Salford)*: In two beds, the first used as a roughing (? straining) filter.

24132 p. 576) 24646 *Dr. Reid*: If character of sewage requires filtration through greater depth than 5 feet, it is better to provide two filters; ordinarily, however, a single fine filter, 5 feet deep, gives excellent results with efficient distribution.

See also 27075 as to experiments at Hanley, from which it is concluded that with fine grade ($\frac{1}{8}$ inch) filters depth need not exceed 2 feet 6 inches; and where an extension of filter capacity is necessary it should be provided by increase of area and not increase of depth.

(74.) Is the Material in Percolating Filters better disposed in the Form of Two Beds, to be fed in Succession, or in One Deep Bed (*continued*).

PERCOLATING FILTERS.

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07 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): From point of view of quality of effluent the medium is probably better disposed in two beds. Important to note, however, that—

(*a*) Two shallow beds more costly to construct.
(*b*) "Suspended solids" from second shallow bed will not be less than that from primary bed.

Comparative experiments have been made (25122).

8 *Messrs. Willcox & Raikes*: Two shallow beds give better results than one deep bed of same capacity, owing to greater facility for aeration.

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(75.) HOW SHOULD PERCOLATING FILTERS BE FED.

Fifth Report: Appendix I.

21171 *Mr. Bolton* (*Heywood*): By means of sprinkling or spreading over the entire area.

21682 *Mr. Campbell* (*Huddersfield*): By distributor which will spray liquor evenly over every unit of area of bed.

22026 *Mr. Harrison* (*Leeds*): Liquid should be evenly distributed, so that each unit of surface receives equal volume in a given time.

22822 *Mr. Fowler* (*Manchester*): Prefers "controlled" filter, *i.e.*, with a fine top layer (as at Friern Barnet and Flixton). Has found that precisely same results can be obtained from two filters, one fed by an expensive distributor and other by a fine top layer.

22926 Judges by practical experiments of his own on a small scale and by his general experience of other places: Friern Barnet, Flixton, etc.

23240 *Mr. Carter Bell* (*Salford*): By mains or jets from the roughing filters.

24432 (p. 576) *Dr. Reid*: Essential object is uniformity of distribution, the sewage being applied in as finely a divided state as possible.

25008 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): Liquid should be distributed uniformly over entire surface of bed.

26109 *Messrs. Willcox & Raikes*: By distributor which will secure uniform application of tank effluent in small doses at regular intervals of time.

For description of distributor in use at Hanley *see* 26187.

(76.) SHOULD THE FEED OF PERCOLATING FILTERS BE INTERMITTENT OR CONTINUOUS.

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Mr. F. Candy: Intermittent. Intermittency allows of working with a smaller head and it prevents growths in surface of filter. Short intervals of rest are most beneficial.

Colonel Harding: Generally agrees with what is said by Mr. Candy (*see above*) as to the advantages of intermittency such as is afforded by the Candy sprinkler.

Alderman Hibbert (Chorley): Attributes the good results at Chorley almost entirely to intermittent working.

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Mr. Bolton (Heywood): Intermittent.

Mr. Campbell (Huddersfield): Intervals of rest required, and these are provided for by spreader.

Mr. Harrison (Leeds): Continuous, if possible, especially with coarse material. (Has tried both methods, 22172–5.)

51 With the particular sprinklers at Leeds, there are irregularities in distribution which results in a filtrate fluctuating in quality; but, if this disadvantage could be avoided, there would be certain advantages in intermittence, *e.g.*, the reduction of growths on surface of filter.

Mr. Fowler (Manchester): Found that a continuous flow at a moderate rate, with occasional intervals of rest, gives better result than intermittent flushes.

Mr. Carter Bell (Salford): Intermittent; working 2 hours, and resting 2 hours.

(76.) Should the Feed of Percolating Filters be Intermittent or Continuous (*continued*).

24432 (p. 576) *Dr. Reid*: Continuous: resting periods being at more or less long intervals.

25009 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): Continuous while the bed is working. Filter requires periodical rest. (Result of careful experimental investigation over considerable period: 25124).

26109 *Messrs. Willcox & Raikes*: Intermittently; have obtained best results where one gallon is discharged on to each superficial yard 200 times in twenty-four hours, *i.e.*, one dose every seven minutes.

(77.) WHAT IS THE BEST FORM OF DISTRIBUTION FOR PERCOLATING FILTERS: WHAT ARE THE CONDITIONS OF A PERFECT DISTRIBUTOR.

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55 *Mr. Baldwin Latham*: Fine top layer of sand secures even distribution. (Refers to Friern Barnet filter.)

Fifth Report: Appendix I.

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173 *Mr. Bolton (Heywood)*: Revolving spreaders. Conditions to be fulfilled are :—

(1) Uniform distribution.
(2) Unaffected by wind or frost.
(3) Work with a minimum of friction.

684 *Mr. Campbell (Huddersfield)*: Form depends upon shape and size of filter. A good distributor should fulfil following conditions :—

(1) Uniform distribution over entire surface of filter.
(2) Liquid should be sprayed in small jets or as fine rain.
(3) No small holes to get clogged.
(4) No complicated mechanism.
(5) Not affected by high winds or frosty weather.

028 *Mr. Harrison (Leeds)*: Best form is by means of sprinklers. The distributor should:—

(*a*) Deliver liquid in a continuous stream on to the surface within wide limits of volume per unit area.
(*b*) Rotate smoothly and easily, and not be materially affected by wind pressure.
(*c*) Have exit holes on the rotating arms large enough to pass particles of growth.
(*d*) Admit of ready cleansing of the interior of the arms.

Tipping troughs, fixed troughs, and tray methods are open to the objection that with rates of flow such as 200 galls. per sq. yard they are very liable to freeze in winter.

822-4 *Mr. Fowler (Manchester)*: Prefers a "controlled" filter of the type at Friern Barnet and Flixton, *i.e.*, with a fine top layer. This serves equally well as a filter fed by an expensive distributor. (Opinion based on actual comparable experiments on a small scale: 22924–6.)

A good distributor must fulfil the following conditions :—

(1) Equal distribution on all parts of the bed.
(2) Not subject to stoppage by friction, wind, stoppage of holes, frost, etc.
(3) Must never discharge more than the bed will purify.
(4) Cost must not be in excess of work done.

(77.) What is the Best Form of Distribution for Percolating Filters: What are the Conditions of a Perfect Distributor (*continued*).

23242 *Mr. Carter Bell* (*Salford*): With sufficient fall available, prefers distribution by spray jets; with limited fall, revolving sprinklers.

24432 (p. 577) *Dr. Reid*: Power driven appliances, such as that at Hanley. The conditions of perfect distributor are:—

(*a*) Uniform and fine distribution without exposing large surface of sewage in fine division to the air.
(*b*) Discharge in such a manner as to achieve slowest rate of travel through the filter.
(*c*) Absence of risk of freezing.

25010 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): One of the best forms is a good spray jet. Conditions to be fulfilled by distributor are:

(1) Uniform distribution.
(2) Distribution in form of fine rain or drops.
(3) Distributor absolutely under control.
(4) Not too expensive.
(5) Few moving or working parts.
(6) Minimum working cost.
(7) Not much head or energy required to work distributor.

26109 *Messrs. Willcox & Raikes*: A distributor which will secure the uniform application of tank effluent in small doses at regular intervals of time. (*See also* 26187).

(78.) IS IT BEST TO PUT ON A PERCOLATING FILTER A FAIRLY CONSTANT AMOUNT OF LIQUID, OR CAN THE AMOUNT SAFELY BE INCREASED IN TIMES OF STORM.

Interim Report: Vol. II. (Cd. 686) 1902.

2187 *Col. Ducat:* Storm water sewage up to $2\frac{1}{2}$ times the normal flow can be put through the Ducat filter. Experience of storms at Hendon (2203–5).

4168-9 *Dr. Rideal:* Storm water flowing through beds quickly does not wash away the bacteria, or otherwise harm the bed.

4659 *Mr. Baldwin Latham:* At Friern Barnet the whole of the storm water goes on to the filters.

7397 *Col. Harding:* Increase of flow due to dilution by storm water can be passed through filter, and will actually be useful in preventing chokage. In storm times, the accumulation of undigestible solids in the beds would be washed out (7425).

Fifth Report: Appendix I.

21174 *Mr. Bolton (Heywood):* A filter could easily deal with a large volume of tank liquor in times of storm. The liquor should be passed on at usual rates, but giving the filters less intervals of rest.

2168 *Mr. Campbell (Huddersfield):* Amount may be increased in time of storm without impairing the efficiency of the filter, and indeed with beneficial results.

22029 *Mr. Harrison (Leeds):* The rate of flow may safely be increased in storm times. With liquids free from suspended matter, the rate of filtration can be increased from 200 gallons to 1,200 gallons per square yard with impunity. (*See also* 21972).

22825 *Mr. Fowler (Manchester):* So far as his rather limited experience goes, thinks that the amount can be increased in storm times without prejudicial effect.

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(78.) Is it best to put on a Percolating Filter a fairly constant amount of Liquid, or can the amount safely be increased in Times of Storm (*continued*).

23243 *Mr. Carter Bell* (*Salford*): A constant amount should be applied, and this should not be increased in time of storm.

Filters at Salford are formed of very fine material. (*See* 23337–44.)

24432 (p. 577) *Dr. Reid*: A constant amount gives satisfactory results for a long period; but rate may be considerably increased periodically, and for a limited period, without impairment in the results.

24041-5 Suggests that filters may be worked at three times ordinary rate for short periods.

25011 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): Best to put in a fairly constant amount of liquid; but quantity can be considerably increased during storm of short duration.

26110 *Messrs. Willcox & Raikes*: Increase in rate of working is temporarily detrimental to results.

(79.) IS THERE ANY PRACTICAL ADVANTAGE IN ARTIFICIALLY HEATING THE LIQUID WHICH IS BEING TREATED ON PERCOLATING FILTERS.

Interim Report: Vol. II. (*Cd.* 686) 1902.

1849 *Mr. C. J. Whittaker* (*Accrington*): One of the chief advantages is that changes in the strength of the sewage can be met.

7392 *Col. Harding*: Filtrates from Leeds filter deteriorated in cold weather. Thinks that in the absence of artificial heating there would be distinct falling off in results during severe frost. This was found to be the case with the Accrington filter at Leeds when it was worked without artificial heating (7414–5).

Fifth Report: Appendix I.

1175 *Mr. Bolton* (*Heywood*): No practical advantage.

1686 *Mr. Campbell* (*Huddersfield*): No.

2030 *Mr. Harrison* (*Leeds*): No.

3244 *Mr. Carter Bell* (*Salford*): Might be some advantage.

4432(p. 577) *Dr. Reid*: No personal experience; but judging from published results, does not think there is much to be gained

6111 *Messrs. Willcox & Raikes*: No.

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(80.) ARE OPEN SIDES AN ADVANTAGE TO A PERCOLATING FILTER.

Interim Report: Vol. II. (Cd. 686) 1902.

2276-83 *Col. Ducat*: There is aeration through the open sides.

3433-4 *Mr. J. Garfield (Wolverhampton)*: Experimented with open sides, but found it better for the air to pass down through the filter with the liquid.

7359
7446 *Col. Harding*: Experience at Leeds seemed to show that side aeration was of very little value. It was found with both the Whittaker and Ducat filters which have open sides that, when the surface was choked, the results became very bad (7372).

Fifth Report: Appendix I.

21176 *Mr. Bolton (Heywood)*: No experiments made ; but assumes that open sides would be advantageous.

21687 *Mr. Campbell (Huddersfield)*: Open sides are essential. Tried both (closed and open) under strictly comparable conditions and found better results from the open (21757). The difference was slight, however — between 5 and 10 per cent. better purification with the open filter (21871–21897.) Value of open sides becomes less as the filtering area increases (21896–7).

22031 *Mr. Harrison (Leeds)*: Side aeration is not necessary. Shown by comparative observations.

22827 *Mr. Fowler (Manchester)*: Apparently no advantage from open sides : aeration takes place from the top. Result of experiments (22975).

23245 *Mr. Carter Bell (Salford)*: Yes. (No experience of his own: 23345).

(80.) Are Open Sides an Advantage to a Percolating Filter (*continued*).

432 (p. 577) *Dr. Reid*: Has not found any advantage.

455 Great nuisance from flies with open sides No such nuisance with closed filters.

013 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): Open sides offer some advantages; but suggests that the construction of filters with open sides is more costly.

112 *Messrs. Willcox & Raikes*: Perforated walls may facilitate aeration near outside of bed, but no material advantage is derived from this in the average quality of the effluent. Very important that under-drains should be ventilated at both ends.

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(81.) COST OF PERCOLATING BED INSTALLATION PER ACRE, AND AMOUNT OF LIQUID TREATED PER ACRE PER 24 HOURS AT ORDINARY TIMES AND IN STORM TIMES.

Interim Report: Vol. II. (*Cd.* 686), 1902.

1641-5 (1593-1600) *Mr. Santo Crimp*: Cost of rough filters at Wimbledon (formed of burnt clay) was about £1,500 per acre. Filters treat satisfactorily 500,000 gallons of chemically precipitated sewage per acre per day. (In operation since 1885.)

4858 *Mr. C. J. Whittaker* (*Accrington*): Cost about £3 per square yard (*i.e.*, about £14,520 per acre). This includes cost of boilers, chimneys, pumps, sprinklers, filtering material, draining bottom of tank, etc. Material, coke. Depth, 9 feet.

4839-42 Amount treated: ordinarily, 1,936,000 gallons per acre per day.
maximum, 2,904,000 ,, ,, ,,

Fifth Report: Appendix I.

21185 *Mr. Bolton* (*Heywood*): Estimate for beds, 8 feet deep, is £9,500 per acre. Propose to treat 643,720 gallons per acre per day in dry weather, and not more than 1,936,000 gallons per acre in wet weather.

21696 *Mr. Campbell* (*Huddersfield*): Cost, £2,500 per acre.

Amount treated—Ordinary times - - - - - 1,500,000 gallons per acre per day.
,, Storm times - - - - - - - 1,880,000 ,, ,, ,,
Depth—7 feet.

Average analysis of effluent in parts per 100,000.

	In ordinary weather.	In storm times.
Nitrogen from free and saline ammonia - - - - -	0·23	0·05
Nitrogen from albuminoid ammonia - - - - - -	0·090	0·049
Nitrogen from nitrates and nitrites - - - - -	1·03	—
Chlorine - - - - - - - - - - -	11·90	10·70
Oxygen absorbed in 4 hours - - - - - - - -	1·29	1·00

(81.) Cost of Percolating Bed Installation per Acre, and Amount of Liquid treated per Acre per 24 Hours at Ordinary Times and in Storm Times (*continued*). PERCOLATING FILTERS.

22038 *Mr. Harrison (Leeds)*: All filters at Leeds are experimental. The cost of the percolating beds, 9 to 10 feet deep, has been about £9,000 to £13,000 per acre, according to manner of construction.

In ordinary times, the amount treated is usually 200 gallons per square yard per day. This is increased in times of storm to as much as 1,200 gallons per square yard per day.

Average analyses are as follows (parts per 100,000):—

I.—Filter treating Septic Tank Effluent and having a depth of 9 ft. 6 in. of Bed Material (1903).

——	Septic Tank Effluents.	Bed Filtrate.	
		Unsettled.	Sand Filtered.
Ammoniacal N.	1·05	·408	·374
Albuminoid N.	·363	·142	·076
Nitric N.	—	·993	1·06
Oxygen absorbed 4 hrs., 80° F.	5·96	1·09	·734
Incubator Test, before	—	·59	·29
Incubator Test, after	—	·61	·32
Dissolved Oxygen absorbed in 24 hours	—	35 per cent.	24 per cent.
Suspended Solids	15·9	11·2	3·0

No storm waters were treated on this filter.

II. Filter treating Settled Sewage and having a depth of 9 ft. 6 in. (1904.)

——	Settled Sewage.	Bed Filtrate.	
		Unsettled.	Sand Filtered.
Ammoniacal N.	1·73	·295	·253
Albuminoid N.	·388	·137	·070
Nitric N.	—	1·27	1·428
Oxygen absorbed 4 hours, 80° F.	5·50	1·64	·945
Incubator Test, before	—	·581	·349
Incubator Test, after		·545	·319
Dissolved Oxygen taken up in 24 hours	—	32·8 per cent.	15·7 per cent.
Suspended Solids	12·2	12·9	6·4

III.—(*a*) Filter 12 ft. deep and Treating Crude Sewage (Screened) 1902 and 1903.

——	Screened Sewage.	Filter Effluent.	
		Unsettled.	Sand Filtered.
Ammoniacal N.	2·30	·721	·516
Albuminoid N.	·769	·277	·104
Nitric N.	—	·350	·591
Oxygen absorbed 4 hours, 80° F.	10·2	3·08	·934
Incubator Test, before	—	1·28	·39
Incubator Test, after	—	2·25	·46
Dissolved Oxygen absorbed in 24 hours	—	71 per cent.	39 per cent.
Suspended Solids	53·2	21·0	3·5

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(81.) Cost of Percolating Bed Installation per Acre, and Amount of Liquid treated per Acre per 24 Hours at Ordinary Times and in Storm Times (*continued*).

(*b*) Same Filter when treating Storm-waters at the rate of 600 gallons per square yard.

———	Storm Water.	Bed Filtrate.	
		Unsettled.	Sand Filtered.
Ammoniacal N.	1·10	·422	·401
Albuminoid N.	·337	·270	·076
Nitric N.	—	·041	·070
Oxygen absorbed 4 hours 80° F.	7·55	4·12	·835
Dissolved Oxygen absorbed in 24 hours	—	100 per cent.	37·5 per cent.
Suspended Solids	68·7	68·1	—

(*c*) Same Filter when treating Storm-waters at the rate of 1,200 gallons per square yard.

———	Storm Water.	Bed Filtrate.	
		Unsettled.	Sand Filtered.
Ammoniacal N.	1·36	·700	·501
Albuminoid N.	·386	·561	·109
Nitric N.	—	·014	·015
Oxygen absorbed 4 hours 80° F.	9·01	10·0	1·00
Dissolved Oxygen absorbed in 24 hours	—	100 per cent.	54·1 per cent.
Suspended Solids	61·5	64·0	—

IV. (*a*) Filter 6 ft. deep and treating Precipitated Sewage at the rate of 100 gallons per square yard per 24 hours :—(1904).

———	Precipitated Sewage.	Bed Filtrate.
Ammoniacal N.	2·06	·310
Albuminoid N.	·300	·069
Nitric N.	—	1·814
Oxygen absorbed in 4 hours 80° F.	4·14	·698
Dissolved Oxygen absorbed 24 hours	—	10·3 per cent.
Incubator Test { before	—	·261
Incubator Test { after	—	·263
Suspended Solids	6·7	2·1

(81.) Cost of Percolating Bed Installation per Acre, and Amount of Liquid treated per Acre per 24 Hours at Ordinary Times and in Storm Times (*continued*).

PERCOLATING FILTERS.

(*b*) Same Filter treating Precipitated Storm-water at the rate of 600 gallons per square yard.

	Precipitated Storm Water.	Bed Filtrate.
Ammoniacal N.	1·38	·357
Albuminoid N.	2·11	·103
Nitric N.	—	1·93
Oxygen absorbed in 4 hours at 80° F.	1·95	1·05
Incubator test { before	—	3·10
Incubator test { after	—	·320
Suspended solids	7·2	7·1

(*c*) Same Filter treating Precipitated Sewage at the rate of 200 gallons per square yard (March, 1905).

	Precipitated Sewage.	Bed Filtrate.
Ammoniacal N.	1·68	·500
Albuminoid N.	·348	·070
Nitric N.	—	1·52
Oxygen absorbed in 4 hours at 80° F.	3·00	·581
Percentage of dissolved Oxygen absorbed	—	13%
Incubator Test { before	—	·21
Incubator Test { after	—	·24
Suspended Solids	5·1	·8

(*d*) Same Filter treating Storm-water at the rate of 1,200 gallons per square yard (March, 1905).

	Precipitated Sewage.	Bed Filtrate.
Ammoniacal N.	1·71	·514
Albuminoid N.	·296	·108
Nitric N.	—	1·13
Oxygen absorbed in 4 hours at 80° F.	2·14	·860
Percentage of dissolved Oxygen absorbed	—	27%
Incubator test { before	—	·362
Incubator test { after	—	·417
Suspended solids	7·1	8·1

6 *Mr. Fowler* (*Manchester*): Manchester percolating filter very costly; but the figures would not be a fair basis of comparison.

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(81.) COST OF PERCOLATING BED INSTALLATION PER ACRE, AND AMOUNT OF LIQUID TREATED PER ACRE PER 24 HOURS AT ORDINARY TIMES AND IN STORM TIMES (*continued*).

23254 *Mr. Carter Bell* (*Salford*): About £5,324 per acre. Filters, 5 feet deep.

AVERAGE ANALYSES.

— —	Tank effluent.	Filtrate.
	Parts per 100,000.	Parts per 100,000.
4 hours Oxygen absorbed	4·7	·69
Free Ammonia	1·95	·60
Alb. ,,	·448	·127
N. as Nitrates and Nitrites	·172	1·651
Suspended matter	2·9	·86
Chlorine	14·1	13·6

24432 (p. 577) *Dr. Reid*: Cost varies according to circumstances of different localities and to nature of construction. Gives figures for three installations as follows:—

Construction.		Distribution.	Preliminary Treatment.	Inclusive cost per acre.
Walls.	Filter Medium.			
1.—Earthen embankments, lined with cement concrete, 5ft. 3in. deep.	Broken shingle. Body ¼in. particles. Top layer ⅛in. particles.	Revolving Distributor. Automatic except during heavy winds when electric power is used.	Chemical Precipitation.	£4,285
2.—Close brickwork above ground. Longitudinal, 4ft. 9in. deep.	Broken 'saggers' ¼in. to ½in. particles.	Power driven by electric motor.	Septic Tank.	£5,500
3.—Entirely under ground, without any lining on sides or bottom. Longitudinal, 5ft. deep.	Coal. ¼in. to ½in. particles.	Spray distribution by pipes on surface of filter.	Chemical Precipitation.	£4,508

The cost of No. 3 would have been considerably less had a less costly medium than coal been used.

24639 The maximum rate of working for a filter 5 feet deep should ordinarily be 200 gallons per square yard: but there must be perfect distribution.

25022 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): Cost of Birmingham (exclusive of land) was £6,300 per acre. Volume treated per acre: 750,000 gallons per day. Depth of beds: 6 feet.

(81.) Cost of Percolating Bed Installation per Acre, and Amount of Liquid treated per Acre per 24 Hours at Ordinary Times and in Storm Times (continued).

Messrs. Willcox & Raikes: Cost about £5,500 per acre. 1,000,000 gallons per acre treated per day. Analyses of tank effluent and filter effluent:—

	Parts per 100,000.	
	Tank effluent.	Filter effluent.
Solids in Solution	105·3	112·0
Solids in Suspension	4·4	·4
TOTAL	109·7	112·4
Chlorine	8·7	8·5
Free Ammonia	1·820	·081
Organic Ammonia	·270	·029
Oxygen absorbed in 4 hours at 80° F.	1·725	·273
Nitric Nitrogen	·09	1·75

PERCOLATING FILTERS.

(82.) WHAT ARE THE CONDITIONS OF AERATION OF PERCOLATING FILTERS.

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22032 *Mr. Harrison (Leeds)*: To maintain efficiency, there must be free admission of air to base of filter, and top surface must be kept free from growths.

22898 *Mr. Fowler (Manchester)*: Comparative experiments show that there is a slightly greater percentage of oxygen in a continuous filter than in contact bed, but difference is not considerable.

26113 *Messrs. Willcox & Raikes*: A fresh supply of air is drawn down into the bed of the filter after each dose of sewage is applied; and the carbonic acid gas is drawn off at the bottom with the effluent (26235).

27075 *Dr. Reid*: Air travels through a filter from above downwards, direction of current probably being mainly due to percolation downwards of sewage and its more rapid flow towards effluent drains. The air carries down with it the products of combustion, and in the bottom layers the action is possibly anaerobic.

(83.) WHAT IS THE MOST CONVENIENT SUPERFICIAL AREA FOR A PERCOLATING FILTER

Interim Report: Vol. II. (Cd. 686), 1902.

87 *Colonel Ducat*: Would limit dimensions of filters to 126 feet long by 36 feet wide. This would give a filter capable of treating 100,000 gallons a day, which might be taken as a unit.

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178 *Mr. Bolton (Heywood)*: The unit should be such a fraction of the total area that, if thrown out of work, the general treatment will not be interfered with.

689 *Mr. Campbell (Huddersfield)*: One acre.

033 *Mr. Harrison (Leeds)*: For large volumes, a diameter of from 100 to 150 feet.

020 *Mr. Fowler (Manchester)*: The unit should be such a fraction of the total area that, if thrown out of work the general treatment will not be interfered with.

247 *Mr. Carter Bell (Salford)*: With fixed sprinklers on square shaped filters, size is immaterial.

015 *Messrs. Watson & O'Shaughnessy (Birmingham)*: Must depend on shape and configuration of site. Large filter is economical, and with certain distributors can be divided into comparatively small units or areas, ½ acre maximum unit for filters fitted with revolving distributors.

114 *Messrs. Willcox & Raikes*: Large travelling distributors, such as those at Hanley, cannot conveniently cover more than half an acre. (*See also* 26230–3.) To provide for fluctuations in flow, the total area should be divided into units except in very small schemes.

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(84.) IS IT DESIRABLE THAT THE BOTTOM OF A PERCOLATING FILTER BE RAISED FROM THE GROUND.

Fifth Report: Appendix I.

21179 *Mr. Bolton (Heywood)*: Yes; important to have false floor so that humus matter can drop free from the filtering material, and so as to ensure better aeration for lower part of bed.

21690 *Mr. Campbell (Huddersfield)*: Yes, to allow effluent to pass away readily and to ensure good aeration.

22082 *Mr. Harrison (Leeds)*: Yes, as there must be free admission of air to base of filter.

22057–61 Means that there must be a given air space between the base of the material and the concrete floor, not necessarily that the bottom of the filter must be above ground level.

22830 *Mr. Fowler (Manchester)*: Only so far as to ensure a perfectly free clearance for water and air at bottom.

23248 *Mr. Carter Bell (Salford)*: Yes.

24432 (p. 577 *Dr. Reid*: Has found in practice no advantage in having bottom of filter above ground.

25016 *Messrs. Watson & O'Shaughnessy (Birmingham)*: Yes, false floor and air space beneath filter absolutely necessary for mechanical reasons as well as for aeration.

26115 *Messrs. Willcox & Raikes*: No; but under drains should not be waterlogged. (*See also* 26235.)

(85.) DO PERCOLATING FILTERS CHOKE: IF SO, HOW CAN THE CHOKING BE REMOVED, AND AT WHAT COST.

PERCOLATING FILTERS

Interim Report: *Vol. II.* (*Cd.* 686), 1902.

9 *Colonel Ducat*: No accumulations in the Hendon filters after four to five months' working with one filter (clinker), and eight to nine months' with the other (coke). A coke filter, however, became choked owing to the disintegration of the coke (2348 : 2374–5).

5-61 *Mr. Baldwin Latham*: At Friern Barnet, where most of the solids are first removed by chemical precipitation, there has been no choking.

7-22 *Mr. C. J. Whittaker* (*Accrington*): No chokage at Accrington (experience of eight months' day and night working). Filters working as freely after two years (*see* 5786–8). Sewage was first settled.

374 *Mr. W. H. Prescott* (*Reigate*): Experimental beds worked on the percolating system with sprinklers at Reigate were found not to choke. Sprinkler beds were self-cleansing.

8-61 *Colonel Harding*: Filter (Whittaker Bed) constructed of very coarse material (above 3 inches in size) to a depth of 12 inches, and for remainder of depth with material from 3 inches to 1 inch in size, was found after twelve months' working to be choked through accumulation of indigestible matter. Filter dealt with septic tank effluent containing 13 grains per gallon of suspended solids.

2-4 A second filter (Whittaker Bed), 9 feet deep, constructed of coarse coke to a height of 1 foot above the drain pipes and with coke not less than $1\frac{1}{2}$ inches in size for remainder, was worked successfully for eight months, when there was some accumulation of indigestible matter. It was found, however, that these solids could be worked out. Perhaps, with a filter of this kind, the accumulated solids would be washed out automatically during storm times by the increase in the flow.

2 An experiment was tried with Ducat filter of fine material (clinker, $\frac{3}{8}$ inch to $\frac{5}{8}$ inch). Crude sewage, after screening, was dealt with. The surface of the filter rapidly become choked.

3 Filters constructed of very coarse material were found not to choke, even when dealing with Leeds crude sewage, as the suspended solids came through. These, however, were in a changed form and reduced in quantity.

1 *Alderman Hibbert* (*Chorley*): The Chorley polarite filters get choked, but are washed out.

Third Report: *Vol. II.* (Cd. 1487) 1903.

78 *Mr. J. Corbett*: No trouble with Salford filters dealing with chemically precipitated effluent. Filters constructed of cinders of a size that will pass through holes of $\frac{3}{16}$ inch and $\frac{3}{4}$ inch diameter (15437–8).

PERCO-LATING FILTERS.

(85.) Do Percolating Filters Choke: if so, how can the choking be removed, and at what Cost (*continued*).

Fifth Report: Appendix I.

21180 *Mr. Bolton* (*Heywood*): Has not found choking to any appreciable extent in a single bed. Any deposit on material can be washed out by passing large volume of liquid on to bed.

21691 *Mr. Campbell* (*Huddersfield*): Properly constructed, they do not choke. Three and a half years' experience of bed which shows no sign of choking although in constant working. Bed is of very coarse material with fine layer on top. Fine surface never gets choked, and results have been uniformly good.

21758–79

22034 *Mr. Harrison* (*Leeds*): Yes, with filtering material too fine or liable to disintegrate. To prevent choking a hard material, not easily disintegrable, and over three inches in diameter, should be used.

22302 From his experience would suppose that with such a material a percolating filter may go on almost indefinitely.

See also Colonel Harding's evidence.

22831 *Mr. Fowler* (*Manchester*): Not in his own experience, but has seen cases of choking.

22991 If suspended matters come through, it is possible to work filters for long periods without chokage

23249 *Mr. Carter Bell* (*Salford*): If properly graded, beds do not choke. Refers to filters dealing with well settled chemical effluent (23350).

24432 (p. 577) *Dr. Reid*: If constructed of fine particles, and not habitually and for long periods overtaxed, there is no choking except what can be remedied by short rest and surface forking.

25017 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): To a certain extent. Top layer of media became choked with a viscid substance after about four to six weeks' work. This can be removed at trifling cost by loosening the surface or by drying and resting for a time.

26116 *Messrs. Willcox & Raikes*: Not if properly constructed and managed

(86.) OF WHAT NATURE ARE THE SUSPENDED SOLIDS IN THE FILTRATE FROM PERCOLATING FILTERS. HOW MUCH IS ORGANIC MATTER, AND ARE THE SOLIDS PUTRESCIBLE APART FROM THE LIQUID.

Fifth Report: Appendix I.

381 *Mr. Bolton (Heywood)*: Granular in appearance, and fairly readily settled. Contain, on an average, 52·5 per cent. inorganic matter and 47·5 per cent. organic matter. The solid matter, apart from liquid, upon incubation, undergoes secondary putrefaction in from three to five days at 80°F.

92 *Mr. Campbell (Huddersfield)*: Solids are brown earthy matter and easily settle. About 55 per cent. organic matter. Not putrescible.

35 *Mr. Harrison (Leeds)*: An analysis of the sludge deposited from a continuous filter effluent gave:—

Loss on ignition	40·4	per cent.
Sand and insoluble matter	18·9	„
Oxides of iron and alumina	31·3	„

Sludge usually non-putrescent.

See also Col. Harding's evidence to the effect that the solids in the Leeds filtrates are usually non-putrescent (7360; 7366–7; 7374; 7387—Interim Report).

32 *Mr. Fowler (Manchester)*: Analysis of suspended solids in Manchester filtrate:—

Moisture	82·29
Mineral (mainly oxide of iron)	9·37
Organic	8·34
Dried residue	—
Nitrogen	2·79
Carbon	23·04
Hydrogen	3·44

Solids putrescible apart from liquid portion.

50 *Mr. Carter Bell (Salford)*: 10 per cent. is organic matter. It is not putrescible.

18 *Messrs. Watson & O'Shaughnessy (Birmingham)*: Partly mineral and partly organic. About 30 per cent. organic. Solids do not appear to putrefy.

797-8 *Mr. F. Scudder*: Granular and readily settled or strained off. The suspended matter is liable to putrefy but is much less objectionable than it was before filtration (25808–10).

PERCO-
LATING
FILTERS.

(87.) TO WHAT EXTENT IS THE ORGANIC MATTER OF THE SUSPENDED SOLIDS IN A PERCOLATING FILTER EFFLUENT DIFFERENT FROM THE ORGANIC MATTER OF THE SUSPENDED SOLIDS GOING TO THE FILTER.

Fifth Report: Appendix I.

21182 *Mr. Bolton (Heywood)*: More granular in appearance; settle more rapidly; and are not as glutinous in character.

21693 *Mr. Campbell (Huddersfield)*: More granular and are non-putrescent.

23251 *Mr. Carter Bell (Salford)*: Not very different.

25019 *Messrs. Watson & O Shaughnessy (Birmingham)*: "Suspended solids" going in to filter contain over 58 per cent. of organic matter. Much of this represents residues from decomposition of organic structures, but it also contains living organisms, some of which are filaments.

The organic matter in filtrate consists almost entirely of living and dead organisms and mucilage. It forms rather less than one-third of the suspended solids.

25130 No direct connection between the suspended matter going on to bed and that coming out in the filtrate.

26117 *Messrs. Willcox & Raikes*: The filtered effluent at Hanley contains no solid matter in suspension.

(88) SUGGESTIONS FOR SETTLEMENT OR OTHER SEPARATION OF THE SUSPENDED SOLIDS IN A PERCOLATING FILTER EFFLUENT.

Fifth Report : Appendix I.

Mr. Bolton (*Heywood*) : Found, by experiment, that greater portion settled in two hours ; in three hours there were only traces ; while at the end of four hours the effluent was practically free. Quite practicable to reduce to a maximum of three parts per 100,000 by settlement.

Mr. Campbell (*Huddersfield*) : Simple settlement will remove bulk. Practicable minimum reduction is to three parts per 100,000.

Mr. Harrison (*Leeds*) : Solids are readily settled out, but mechanical filtration is a better and more effective process. Suggests a filter of fine furnace ashes, six inches deep, with side walls rising about two feet above the surface of the ashes. This will reduce 11 parts per 100,000 to 4 or 5 parts per 100,000, at a rate of filtration of 400 gallons per square yard.

Mr. Fowler (*Manchester*) : Settlement inadequate for Manchester filtrate. Straining filter is necessary and reduction to, say, an average of two grains and a maximum of three should fulfil all practical requirements.

Mr. Carter Bell (*Salford*) : Amount of suspended matter insignificant at Salford.

Messrs. Watson & O'Shaughnessy (*Birmingham*) : Experiments give following results :

(*a*) Downward sand filtration very efficient, but costly.
(*b*) Upward sand filtration not successful ; difficulty in cleansing.
(*c*) Sedimentation in long shallow trenches removed bulk of suspended matter down to an average of about 5 parts per 100,000.
(*d*) Sedimentation in shallow tanks not successful.
(*e*) By a tank called " Birmingham Separator " (something like a Dortmund tank), suspended matter is eliminated at cost of about 1s. 6d. per mill on gallons.

Mr. F. Scudder : Prefers sand filtration.
Settlement is very satisfactory. With a series of shallow tanks good results can be obtained.

Messrs. Willcox & Raikes : Suspended matter should be removed by straining through sand.

PERCO-
LATING
FILTERS.

(89.) WHAT IS THE ACTION OF PERCOLATING FILTERS WITH REGARD TO THE OXIDATION OF (*a*) THE AMMONIACAL AND ORGANIC MATTER IN SOLUTION; (*b*) THE ORGANIC MATTER IN SUSPENSION.

Fifth Report: Appendix I.

22837 *Mr. Fowler* (*Manchester*): As regards (*a*), much depends on size of material and consequent proportion of liquid held up in interstices. A certain proportion of liquid goes through filter very rapidly: the remaining proportion takes much longer time. (*b*) The organic matter in suspension is certainly changed; but further investigation is necessary.

24432 (p. 578) *Dr. Reid*: Made no experiments, but from observation of working of filters has obtained following impressions:—

As regards (*a*): If filter is working well with normal sewage, high standard of oxidation is affected in about seven minutes, the time taken for sewage to pass through fine grain filter five feet deep.

As regards (*b*): Organic matter in suspension is liquefied in upper layers, and, passing downwards, becomes oxidised with organic matter previously in solution. (This applies only to fine grain filters: in coarse filters, large proportion of suspended matters pass through with effluent.)

25023 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): No direct experiments with regard to (*a*), but noticed that, with very efficient aeration, first action is oxidation of ammonia with comparatively little action organic matter. With less efficient aeration and prolonged sojourn in bed, there is a lower nitrification with greater elimination of gaseous nitrogen and reduction of dissolved organic matter.

As regards (*b*), organic matter in suspension appears to be retained in the upper layer, *i.e.*, first fifteen inches. This is of smaller size material than rest of bed. Putrefaction, rather than oxidation, would seem to predominate.

(90.) DO AMMONIUM SALTS AND ORGANIC SUBSTANCES IN SOLUTION, NOT OF A COLLOIDAL NATURE, PASS RAPIDLY THROUGH A PERCOLATING FILTER, OR ARE THEY FIRST ABSORBED BY THE FILTERING MATERIAL OR BY GROWTHS ON THAT MATERIAL, SO THAT THEIR PASSAGE THROUGH THE FILTER IS A VERY GRADUAL ONE. **PERCO-LATING FILTERS**

Fifth Report: Appendix I.

37 *Mr. Fowler* (*Manchester*): Laboratory experiments show that ammonium salts are absorbed by washed and sterile clinker, and he has little doubt that their passage through filter is in reality very slow, a constant sequence of physical and chemical changes taking place depending upon character and size of material, its condition, variations in strength of liquid, and rate of application. In general, the action of filter tends to the formation of nitrates, by oxidation of ammonia, rather than to the breaking down of complex organic compounds in solution.

24 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): From observations of filters generally, take the view that the capacity of filter for abstracting dissolved matters is very largely if, not entirely, a function of the proportion of medium surface presented to the liquid.

PERCO-
LATING
FILTERS.

(91.) WHAT ARE THE EFFECTS OF CHANGES OF ATMOSPHERIC TEMPERATURE ON THE WORKING OF A PERCOLATING FILTER.

Fifth Report: Appendix I.

21188 *Mr. Bolton (Heywood)*: Has not found that changes of temperature have any great effect on working of beds.

21699 *Mr. Campbell (Huddersfield)*: Works equally well in hot or cold weather. Statement based upon careful observations over a period of three and a half years, and upon analyses of filtrates during summer and winter (21898–21904).

22039 *Mr. Harrison (Leeds)*: Gives figures showing (1) that the amount of ammoniacal nitrogen in the filtrate approximately increases with a decreasing temperature and (2) that the purification in albuminoid nitrogen and the oxygen absorbed value decreases approximately with a decreasing temperature.

22838 *Mr. Fowler (Manchester)*: Has noticed that unless the effluent is kept constantly moving by the distributor, it will freeze in cold weather.

23257 *Mr. Carter Bell (Salford)*: Made no observations, but thinks the higher the temperature the better the effluent.

24432 (p.578) *Dr. Reid*: Not materially affected when active nitrifying properties are once established in filter.

25025 *Messrs. Watson & O'Shaughnessy (Birmingham)*: Ordinary changes of temperature do not materially affect working, but purification in winter appears to be less than in summer.

26123 *Messrs. Willcox & Raikes*: Atmospheric temperature does not affect working of percolating beds. (*See* also 26223–6.)

(92.) IS THERE ANY TROUBLE FROM VEGETABLE GROWTHS IN PERCOLATING FILTERS. IF SO, WHAT ARE THE CAUSES OF THE GROWTHS, AND HOW CAN THEY BE PREVENTED.

PERCOLATING FILTERS.

Interim Report : Vol. II. (Cd. 686) 1902.

0 *Mr. C. J. Whittaker (Accrington)* : No trouble from growths at Accrington.

56-7 *Col. Harding :* Filter at Leeds, constructed on lines of Whittaker filter, was choked by abundant gelatinous growth on surface. Probably due to the artificial heating of the effluent.

36 There was also Pylobelus growth on surface of Leeds coke filter. Working at 200 gallons per square yard, the growth did not choke surface ; but at 400 gallons per square yard, the growth was excessive.

53-4 Suggests that discharging effluent on to filter intermittently has some effect in preventing Pylobelus growth. (Experience with Candy sprinkler.)

Fifth Report : Appendix I.

189 *Mr. Bolton (Heywood)* : When supply was continuous, gelatinous mass grew on surface. This was prevented by working intermittently.

700 *Mr. Campbell (Huddersfield)* : Has found no trouble from growths.

2040 *Mr. Harrison (Leeds)* : Growths in quantity appear on the Leeds filters in the early and later periods of the year, indicating that the change of temperature of the sewage is the cause. It is necessary to repeatedly fork the surface at such times.

2839 *Mr. Fowler (Manchester)* : There is a tendency for slimy growths to appear on surface where large quantities of unpurified effluents are applied in one place. The remedy appears to be to apply less per square yard, or to carry preliminary treatment further.

3258 *Mr. Carter Bell (Salford)* : No trouble from vegetable growths with Salford filters.

PERCO-
LATING
FILTERS.

(92.) Is there any Trouble from Vegetable Growths in Percolating Filters. If so, what are the Causes of the Growths, and how can they be Prevented (*continued*).

25026 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): Vegetable growths of nature of cladothrix give trouble by choking surface of medium. Forking over prevents this to some extent.

26124 *Messrs. Willcox & Raikes*: Experiments at Hanley showed that growths were more likely to occur on large sized material than on small sized. Where large and small material were used in same filter, green growth was found on former but nothing on latter. This growth was, however, only green moss and not a growth of the sewage fungus type (26235–40). Not experienced growths of latter type (26240).

(93.) IS THERE ANY NUISANCE FROM THE TREATMENT OF SEWAGE ON PERCOLATING FILTERS.

PERCOLATING FILTERS

Fifth Report : Appendix I.

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0 *Mr. Bolton (Heywood)* : Odour from percolating bed is much more in evidence than that from a contact bed, and risk of nuisance is greater. Nuisance probably arises from the spraying and not from the filtration (21386-7.)

01 *Mr. Campbell (Huddersfield)* : No.

40 *Mr. Fowler (Manchester)* : Never noticed any appreciable smell ; but has observed, in several cases, an extraordinary development of insect life, flies, spiders, etc.

59 *Mr. Carter Bell (Salford)* : No ; but there may be a little odour occasionally in hot weather.

32 (p. 578) *Dr. Reid* : Yes, especially where sewage contains brewery waste in considerable proportion.

027 *Messrs. Watson & O'Shaughnessy (Birmingham)* : No.

125 *Messrs. Willcox & Raikes* : No.

FILTERS (INCLUDING CONTACT BEDS) IN GENERAL.

(94.) WHAT ARE THE COST AND RELATIVE ADVANTAGES OF PERCOLATING FILTERS AND CONTACT BEDS. IS ONE FORM BEST FOR SOME KINDS OF SEWAGE, AND THE OTHER FORM FOR OTHER KINDS OF SEWAGE.

Interim Report: Vol. II. (*Cd.* 686) 1902.

264 *Mr. R. A. Tatton*: Continuous filters worked on Chorley principle take more liquid than contact beds, but the initial cost per square yard is greater and so is the cost of maintenance.

2187 *Col. Ducat*: Disadvantages of contact bed system :—

(*a*) The filtrate is not of uniform purity. The first discharge from the filter is of much less purity than the discharge when the bed is nearly empty.
(*b*) Not practicable to work beds in regular cycles of filling, standing full, emptying, and resting, owing to the unequal flow of sewage, rendered more variable by storm water.
(*c*) The beds must be large enough to deal with storm flow, and this increases initial cost by about 60 per cent.
(*d*) More personal supervision is required.

Advantages of percolating filters :—

(*a*) Simplicity of working: the sewage is automatically distributed over surface, and filtrate runs off in a constant flow without intervention of valves or human agency.
(*b*) The rate of filtration can be increased in storm times, as there are no additional impurities in the sewage.
(*c*) One man would be sufficient to supervise a large installation (ten filters).
(*d*) The initial outlay in most cases would probably be less and the working expenses are small.

4505 *Mr. Baldwin Latham*: Contact beds require more constant attention than percolating filters.

6936 *Mr. W. H. Prescott*: Experience at Reigate was that the percolating system was much more efficient than the contact system.

7394 *Col. Harding*: Experience of contact beds for nearly three years and of trickling filtration for nearly two years leads to the conclusion that, with the same depth, similar analytical results may be obtained by either system as regards albuminoid ammonia and oxygen absorbed; but trickling filtrates contain more nitrates and more dissolved oxygen. Again, the experiments show that in trickling filtration the filtering material is less disturbed and the life of the filter is very much greater. Apparently, trickling filtration over coarse material can be continued many years without renewal of material, and the filter will not be choked by indigestible solids as is the case with contact beds.

Fifth Report: Appendix I.

21191 *Mr. Bolton* (*Heywood*): Percolating beds can be constructed at less cost than double the area of contact beds with necessary inlet and outlet channels, valves, etc.

Advantages of percolating filter over contact bed :—

(*a*) Upper layers of filter do not become choked so soon.
(*b*) More easily cleaned.
(*c*) Being more compact, requires less supervision.
(*d*) More perfect distribution can be obtained.
(*e*) Can be worked more automatically.
(*f*) More suitable for Heywood sewage, and for sewages generally.

(94.) What are the Cost and Relative Advantages of Percolating Filters and Contact Beds. Is one Form best for some kinds of Sewage, and the other Form for other kinds of Sewage (*continued*).

FILTERS (INCLUDING CONTACT BEDS) IN GENERAL.

1 *Mr. Campbell* (*Huddersfield*): Contact beds are more costly, both as regards initial expenditure and upkeep The advantages of percolating beds over contact beds are :—

(1) Do not require so large an area.
(2) Do not require retaining walls.
(3) Do not lose their capacity.
(4) Usually produce effluent richer in dissolved oxygen and in oxidised nitrogen.
(5) Irreducible matter comes away in effluent.

In his experience, contact beds are not adapted under any circumstances for large sewage schemes.

9-49 Both the washing and the renewing of material of contact beds are impracticable financially.

1 *Mr. Harrison* (*Leeds*): Relative advantages and disadvantages are :—

(1) If solids are present in liquid, a greater depth of filtering material is required for percolating beds.
(2) Percolating filters cost more to construct. (Greater depth and need for efficient aeration that entails extra cost : 22063–5.)
(3) If solids are present in the liquor to be treated, they are present in the filtrate from percolating beds, necessitating further settlement or filtration. Contact bed filtrates are practically free from suspended solids.
(4) As a general rule, filtrate from percolating bed contains more dissolved oxygen.
(5) Amount of liquid which can be treated on contact beds is limited by number of fillings, and decreases in amount as beds lose capacity. Percolating filters can treat a constant amount for years, if material is coarse and not easily disintegrated.
(6) Accumulation of solids in contact beds in time causes great loss of capacity which can only be regained by washing the bed material. Accumulation of solids in coarse percolating filters may easily be washed out. Generally speaking, the effective life of a percolating filter will be longer than that of a contact bed.
(7) Contact beds are less readily affected by changes in atmospheric temperature than percolating beds.

79 *Mr. Valentine* (*Oldham*): No practical experience of percolating filters, but suggests following points of comparison :—

(*a*) Initial outlay likely to be greater in the case of percolating beds. (Cost of construction higher, in addition to which is cost of mechanical distribution.)
(*b*) Owing to depth of percolating beds, pumping may be necessary in some cases.

On the other hand—

(*c*) The cost of upkeep is likely to be smaller in the case of percolating filters than in the case of contact beds, because the latter are so liable to be choked.

Generally, the advantage of one system over another must depend upon the circumstances, *e.g.*, amount of land available, whether labour is cheap, whether filtering matter of suitable kind can readily be obtained, etc. Thinks that percolating system will more readily adapt itself to septic tank liquids which are less complex than settled or precipitated sewage.

341 *Mr. Fowler* (*Manchester*): Hands in following Table of comparative data obtained from various sources.

FILTERS (INCLUDING CONTACT BEDS) IN GENERAL.

TABLE HANDED IN BY MR. FOWLER.

COMPARATIVE DATA RE FILTRATION OF TANK EFFLUENT.

——	Manchester.		Accrington.	Burnley.	Oldham.	Birmingham.
Population	574,800		50,000	98,400	154,000	750,000
Character of sewage (purely domestic or manufacturing).	Manufacturing.		Domestic and Trade.	Principally domestic.	Mainly domestic (great proportion of slop water-closets).	Domestic and manufacturing.
Dry weather flow per head of population	40		$24\frac{1}{4}$	25	$17\frac{3}{4}$	30
Average flow per head of population	60		$35\frac{3}{4}$	—	1902. 28·6 1903. 40·2	40 (approx.)
	½-acre beds.	Storm beds.				
Tank treatment: Chemical	—	Chemical.	—	—	—	—
Tank treatment: Sedimentation	—	Sedimentation.	—	—	Sedimentation.	Sedimentation.
Tank treatment: Septic	Open septic.	—	Two series of three open septic tanks.	Open septic tanks (with very large detritus tanks).	About ⅛ of flow through experimental closed tank.	Septic.
Filtration system: Intermittent	Intermittent.	Intermittent.	—	Intermittent.	Intermittent.	Mainly land treatment.
Filtration system: Continuous	—	Streaming.	Continuous.	—	Occasionally streamed in time of storm.	Continuous.
Size of filtering medium	3/16 in. and upwards	Ungraded clinker, free from dust. Large clinker round drains.	2 to 3 in.	Primary beds ¾ in. and upwards. Secondary beds ⅛ in. to ¾ in. (The above are both washed and screened.)	Ungraded clinker, &c., free from dust. Large clinker round drains.	2½ in., 1½ in. 1 in., and ½ in.
Percentage purification on tank effluent—					Jan.-May.	
4 hours' oxygen test	68 per cent.	75 per cent.	77 per cent.	87 per cent.	1903. 73·7 1904. 75·4	—
Albuminoid	59 per cent.	72 per cent.	75 per cent.	87 per cent.	1903. 57·9 1904. 56·7	—
Percentage of free ammonia in tank effluent appearing as nitrite and nitrate in filtrate.	17 per cent.	36 per cent.	60 per cent.	29 per cent.	1903. 12·7 1904. 12·2	—
Average quantity dealt with per acre yard per day during one year, including all rests.	431,000	377,000	645,300	169,400 by double contact.	1903. 286,000 1904. 363,426 exclusive of storm-water.	—
Construction cost per acre yard	£2,376	£1,765	£3,630	£1,300	£800 (approx.)	£3,000
Working cost of beds per million gallons filtered (apart from renewal of material and miscellaneous expenses of works management), average per annum.	3s. 8d.		1s. 11d.	7s. 6d.*	1903. 6s. 3·3d. 1904. 4s. 8·3d.	£20 per ¼ acre bed per annum.
Renewal cost per acre yard per annum, average	£50 (estimated from Burnely results).	£40	Nil.	—	£41 7s.	Nil.
Renewal cost per million gallons filtered	6s. 6d.	5s. 9d.	Nil.	16s.	7s. 11d.	Nil.
Cost of sludge disposal per million gallons of sewage	10s. 3d.	—	2s. 8d.*	5s. 8d.	14s. 1d.	3d. per ton.
Total cost of treatment per million gallons—					1902. / 1903.	
Dry weather flow	£1 13s. 5d.	—	£3 7s. 0d. †	£3 7s. 6·7d.†	— / —	—
Total flow	£1 2s. 3·9d.	—	£2 4s. 8d.	—	£1 14 8d. / £1 4s. 8d. †	—
Cost per head of population per annum	5·85d.	—	7·12d.	7·39d.	2·69d. / 4·33d.	—
Remarks	The total cost of treatment does not include renewal costs, which have not yet been incurred. On the other hand, the cost of sludge disposal will probably be reduced in the future.		* The sludge is lagooned and sold; the cost given is the net cost. † The total cost is largely due to pumping, which it is intended shortly to dispense with.	Cost of working beds, sampling, weeding, and cleaning and levelling distributing troughs. †Total expenditure £2,866 8s. Receipts from sludge manure and crops £400 8s. Net cost £2,466.	† Abnormal rainfall of 1903 reduces cost per million gallons.	—

(94.) WHAT ARE THE COST AND RELATIVE ADVANTAGES OF PERCOLATING FILTERS AND CONTACT BEDS. IS ONE FORM BEST FOR SOME KINDS OF SEWAGE, AND THE OTHER FORM FOR OTHER KINDS OF SEWAGE (*continued*).

FILTERS (INCLUDING CONTACT BEDS) IN GENERAL.

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341 *Mr. Fowler* (*Manchester*)—continued.

His conclusions upon the data are :—

(1) Not possible to lay down any general rule that one system is to be preferred ; particular system to be adopted must depend on local conditions.
(2) Percolating filters more expensive in first cost.
(3) Contact beds are cheaper, if percolating filters necessitate pumping.
(4) For purposes of comparison, cost should be calculated on dry-weather flow.
(5) Contact beds are cheaper under all circumstances where a sufficient area can be obtained at a low cost of construction.

582 *Mr. Wike* (*Sheffield*) : No practical experience of percolating filters, but from results of inquiries, thinks that contact beds would be the cheaper form. Does not see how percolating filters could have any advantage over contact beds, which give satisfactory results at comparatively small cost.

432 (p.578) *Dr. Reid* : Both as regards initial expenditure and annual cost of upkeep and working, contact beds are more costly, because :—

(1) To obtain corresponding results, double contact is required as against single filtration for percolating filter, and twice as much filtering material.
(2) Automatic gearing is required for working contact beds, or manual labour. (This equals cost of distributors.)
(3) Contact beds must generally be of more substantial construction.
(4) Contact beds liable to clog.

Considers that small-particle filters are greatly superior to contact beds, no matter what kind of sewage is dealt with.

461–3 Decidedly of opinion, from his experience in Staffordshire, that single contact effluent is inferior to single filtration in percolating filter, the amount of material being the same.

028 *Messrs. Watson & O'Shaughnessy* (*Birmingham*) : Advantages of percolating beds over contact beds :—

(*a*) Contact beds rapidly choke up ; percolating filters, if properly constructed, do not.
(*b*) Percolating beds take more liquid per unit than contact beds.

Advantages of contact beds over percolating filters :—

(*c*) More suspended matter in percolating bed filtrate than in contact bed filtrate.
(*d*) There is greater loss of total combined nitrogen in contact beds.

405 Advocate use of percolating filters in preference to contact beds, because of the loss of capacity in latter.

408–12 Cost per million gallons, taken in conjunction with strength of sewage, would be rather less with percolating filters.

415–6 Not had large experience of contact beds.

758–60 *Mr. F. Scudder* : Percolating filters infinitely superior as they produce a fully oxidised effluent rich in nitrates. Contact beds will not give such a highly oxidised effluent. The percolating effluent will also maintain more dissolved oxygen.

775 A contact bed after being in operation two or three years gets sensitive in its action, and wants a great deal of care and attention to keep it effective. A percolating filter throws off the suspended matter in a granular form and all difficulties are removed and the life of the filter continues energetic for an unlimited period.

126 *Messrs. Willcox & Raikes* : Contact beds are more costly and less efficient than percolating filters.

FILTERS INCLUDING CONTACT BEDS) IN GENERAL.

(95.) IS THE CHANCE OF NUISANCE ANY GREATER WITH ONE FORM OF FILTER THAN WITH ANOTHER.

Fifth Report: Appendix I.

21192 *Mr. Bolton (Heywood)*: The risk of nuisance is greater with a percolating bed, as the method of distribution tends to liberate any offensive gases or odours.

21486 *Mr. Kershaw (Rotherham)*: Filters fed by means of jets, sprays, or sprinklers are more likely to cause nuisance than contact beds fed in the ordinary manner. Risk depends largely on the preliminary treatment, *e.g.*, strong septic tank liquors when sprayed or sprinkled are most likely to cause nuisance. No nuisance from contact beds. Experience of percolating filters very limited.

21703 *Mr. Campbell (Huddersfield)*: No, both forms free from smell.

22480 *Mr. Valentine (Oldham)*: Makes no comparison; but suggests that the spraying of liquors upon percolating filters generally gives rise to a sour, disagreeable odour.

22041* *Mr. Harrison (Leeds)*: Has never found that actual filtering operations cause nuisance. Risk of nuisance depends upon the nature of the preliminary treatment and the method of distribution, *e.g.*, the distribution of septic liquor by spraying devices may cause a nuisance.

22840
22842 *Mr. Fowler (Manchester)*: Has noticed an extraordinary development of insect life in connection with percolating filters. Apart from this, has experienced no nuisance from filters worked as "controlled" filters. Never had any nuisance from contact beds.

24432 (p.579) *Dr. Reid*: Not with proper management. Real trouble is connected with the delivery to the bed.

25029 *Messrs. Watson & O'Shaughnessy (Birmingham)*: The spray jet form of distribution for percolating filters gives off a smell, but it does not amount to a nuisance. Septic sewage generally gives off less objectionable smell than non-septic sewage. Apparently no real nuisance from either form of filter.

26127 *Messrs. Willcox & Raikes*: No: but septic tank effluent will always cause a nuisance if exposed to the air in sprays and so will any solid matter which accumulates on the surface of filter.

FILTERS (INCLUDING CONTACT BEDS) IN GENERAL.

(96). WHAT ARE THE COMPARATIVE WORKING CAPACITIES OF THE TWO FORMS OF FILTER.

Fifth Report : Appendix I.

93 *Mr. Bolton* (*Heywood*) : Double contact beds : 85 gallons per cubic yard.
Percolating filter : 100 gallons per cubic yard.
Much better effluent from the percolating bed. (Both dealing with the same liquid : 21389.)
The following are comparative analytical figures :

—	Contact System.		Percolating System.		
	Tank.	2nd Contact	Tank.	Bed Effluent.	Settled Effluent (two hours).
Oxygen absorbed (4 hours' test)	5·25	1·08	5·54	1·22	0·83
Ammoniacal nitrogen	1·36	·49	3·40	·51	·51
Albuminoid nitrogen	·38	·10	·78	·12	·10
Nitric nitrogen	nil	·66	nil	1·46	1·40
Chlorine	7·7	7·6	8·3	8·1	8·1
Solids in suspension	—	—	9	5	1·5

03* *Mr. Campbell* (*Huddersfield*) : Amount of septic tank liquor treated :
(*a*) By trickling filter, 132 gallons per cubic yard per day.
(*b*) By double contact beds, 72 gallons per cubic yard per day.

Analysis of liquor treated.	*Parts per 100,000.*
Nitrogen from free and saline ammonia	1·91
Nitrogen from free albuminoid ammonia	0·499
Chlorine	12·10
Oxygen absorbed in four hours	6·16

The filtrate in each case was considered satisfactory by reason of its non-putrescibility.

42 *Mr. Harrison* (*Leeds*) : (*a*) *Percolating filters* :

Liquor treated.	*Depth of bed.*	*Rate per cubic yard per day.*
Crude sewage	12 feet	42 gallons
Septic tank liquor	9½ „	53 „
Settled sewage	9½ „	61 „
Precipitated sewage	6 „	48 „
Precipitated sewage	6 „	100 „

(Results satisfactory.)

(*b*.) *Contact beds.* (Double contact necessary).

Liquor treated.	*Depth of bed.*	*Rate per cubic yard per day.*
Crude sewage (3 fillings per day)	3 feet	128 gallons at first.
		29 „ at end of two years.
Septic tank liquor (2 fillings per day)	6 „	33 „ for 1904 and 1905.

Generally, the average amount treated per cubic yard is greater on a percolating bed than on a contact bed.

181 *Mr. Valentine* (*Oldham*) : Has made no comparative observations ; but thinks that with a liquid absorbing 3½ parts per 100,000 of oxygen in four hours from permanganate, there would be little difference between the two systems. But the working capacity of contact beds diminishes in course of time, which is apparently not the case with percolating beds. Suggests that with a strong liquor the advantage would possibly lie with the percolating filter, while with a more or less diluted tank liquor the contact bed would work more satisfactorily, as the times of filling, standing full, etc., can be lengthened or shortened at will.

343 *Mr. Fowler* (*Manchester*) : Hands in table of comparative analytical results from continuous filter and contact bed worked under comparable conditions at the same rate in each case, viz., up to a maximum of 100 gallons per cubic yard. The conclusion is that, within certain limits, a unit of material in one form of filter has the same purifying effect as a unit in the other (22980–1).

TABLE HANDED IN BY MR. FOWLER.

ANALYTICAL RESULTS.

A. Continuous Filter. B. Contact Bed.

Amount of Septic Tank Effluent dealt with being the same in each case, being gradually increased up to about 100 gallons per cube yard.

Date.	4 Hours' Oxygen Test.			Ammoniacal Nitrogen.			Albuminoid Nitrogen.			Nitrous Nitrogen.		Nitric Nitrogen.		Incubation (3 Minutes' Oxygen Test).						
Month, 1904–5.	Tank Effluent.	A.	B.	Tank Effluent.	A.	B.	Tank Effluent.	A.	B.	A.	B.	A.	B.	Tank Effluent.	A. Before.	A. After.	A. Putrescibility.	B. Before.	B. After.	B. Putrescibility.
April	15·66	2·01	1·94	2·84	1·88	1·60	·65	·10	·09	·07	·04	1·03	·88	8·14	1·01	·77	0/17	1 04	·79	0/17
May	15·73	2·16	2·21	3·14	2·25	1·89	·69	·12	·10	·07	·06	1·19	·98	9·10	1·16	·86	0/10	1·21	·94	0/10
June	8·93	1·69	2·34	3·46	1·65	1·67	·35	·12	·14	·06	·05	1·23	·79	4·56	·74	·63	½/7	1·04	·84	0/7
July	11·73	1·40	1·64	2·99	1·21	1·35	·41	·10	·10	·07	·05	·83	·61	6·19	·69	·61	0/8	·84	·67	0/8
August	17·80	1·53	1·67	3·44	1·45	1·57	·76	·09	·11	·08	·05	·87	·56	7·69	·74	·69	0/6	·86	·80	0/6
September	21·30	2·43	2·77	3·36	1·55	1·59	·85	·15	·15	·07	·05	·92	·67	8·56	1·21	·93	0/5	1·49	1·39	2/5
October	12·07	3·13	3·29	2·59	1·81	1·81	·53	·17	·19	·08	·04	·68	·48	6·26	1·61	·90	0/4	1·86	2·11	2/4
November	9·86	3·40	3·69	2·41	1·93	1·87	·38	·20	·19	·04	·04	·59	·47	5·23	1·96	1·91	1/4	2·20	2·29	3/4
December	9·97	2·13	2·99	2·39	1·32	1·23	·40	·14	·17	·03	·04	1·06	·72	4·37	1·03	·77	0/2	1·57	1·39	0/2
January	9·64	4·56	3·44	2·47	1·92	1·41	·39	·15	·15	·03	·06	·54	·26	4·90	1·70	1·41	0/3	1·94	1·90	½/3
February	11·20	5·46	4·01	2·76	2·15	1·94	·48	·28	·20	·06	·04	·28	·19	5·77	3·09	3·56	1/2	2·23	2·61	1/2
March	7·17	2·50	2·73	1·94	1·22	1·02	·29	·12	·13	·06	·06	·83	·53	3·63	1·40	1·13	0/5	1·51	1·49	1/5
Average	12·59	2·70	2·71	2·81	1·69	1·57	·52	·15	·15	·06	·05	·83	·60	6·20	1·36	1·19	2½/73	1·49	1·43	9½/73

Note.—The filters were constructed of similar-sized material, *i.e.*, ordinary cinders screened over a 3/16″ mesh, very small proportion of coarse material.

(96.) WHAT ARE THE COMPARATIVE WORKING CAPACITIES OF THE TWO FORMS OF FILTERS (*continued*).

FILTERS (INCLUDING CONTACT BEDS) IN GENERAL.

32 (p.579) *Dr. Reid*: A fine-particle percolating filter, 5 feet deep, will efficiently purify, for an indefinite period, at the rate of 120 gallons per cubic yard per day.

To obtain the same results by contact beds, the cubic capacity must be about double that of the percolating filter.

62. *Mr. F. Scudder*: A percolating filter will deal with a greater volume of liquid per cubic yard of material than a contact bed. A 60-feet diameter percolating filter, 9 feet deep, will deal with 100,000 gallons of tank effluent per day, or a little over 300 gallons to the square yard. Has determined this by actual experience. (No figures given as regards contact beds.)

28 *Messrs. Willcox & Raikes*: Far better results have been obtained from percolating filters 14 inches deep than with double contact beds 3 feet deep working at same rate and with tank effluent of same composition.

82 At Hanley, contact beds treating 200 gallons per square yard per day were clogged very soon; but percolating beds treating more than double that quantity were not clogged after 2½ years' working—same size material used but clinker in contact beds and saggers in percolating bed (26183–4).

FILTERS (INCLUDING CONTACT BEDS) IN GENERAL.

(97.) HOW WOULD THE WORKING CAPACITY OF FILTERS VARY WITH VARIATIONS IN THE STRENGTH OF THE TANK LIQUOR.

Fifth Report: Appendix I.

20802 *Messrs. Raymond Ross & Pickles (Burnley)*: The strength of tank effluent in reference to number of fillings on contact beds would be gauged by the volume of sewage as compared with normal flow.

21194 *Mr. Bolton (Heywood)*: Not practicable to vary the amount treated according to strength of sewage.

21487 *Mr. Kershaw (Rotherham)*: Taking oxygen absorbed as the standard of strength, contact beds at Rotherham will bring about a purification of about 50 to 60 per cent. of the tank liquor.

21704 *Mr. Campbell (Huddersfield)*: With weak tank liquors, probably half as much again could be treated. Would rely on albuminoid nitrogen and oxygen absorbed figures for defining "strength" of liquor.

22844 *Mr. Fowler (Manchester)*: Amount treated on Manchester contact beds varies from 350,000 gallons in dry weather to as much as 1,000,000 gallons per acre per day in wet weather. Chlorine number is taken as index of strength.

As a matter of practice it is not always possible to adjust the rate of treatment exactly to the strength.

24432 (p.579) *Dr. Reid*: The working capacity of a fine-grain filter depends upon the volume, that being the factor which determines the degree of aeration of the filter, rather than the strength of the sewage; is not confident that same is true of contact beds or large particle filters.

25031 *Messrs. Watson & O'Shaughnessy (Birmingham)*: There would be variations within narrow limits. Albuminoid ammonia and oxygen absorbed relied on for defining strength of liquor.

26129 *Messrs. Willcox & Raikes*: There may be some variation, but it would not vary directly with the strength of the tank liquor. Filter can only deal with a certain quantity, and this quantity must not be exceeded no matter how weak the sewage may be (26241).

(98.) STORM WATER FILTERS.

STORM WATER FILTERS.

Fifth Report: Appendix I.

Mr. Bolton (*Heywood*): Action of storm water filters is more mechanical than chemical. No time for bacterial action. There is merely a retention of part of the suspended solids.

Mr. Valentine (*Oldham*): Storm water filters would work more efficiently if used intermittently at short intervals, and there would be advantage in using them regularly, *e.g.*, for the filtration of Sunday flow of sewage.

-6 *Mr. Fowler* (*Manchester*): Hands in Table (*see* next page) of examples of storm water treatment in filters. In early stage it is necessary that storm water filters should be supplied with sewage in dry weather.

Storm water filter must be of fine material, and if it is fine a large part of suspended matter must first be settled.

82. Satisfactory results were obtained with a rough cinder bed 15 inches deep. Was working six months with two fillings per day of dry weather flow (chemically precipitated effluent), and as a streaming filter in times of storm. There was no choking and the filtrates were for the most part non-putrescible.

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EXAMPLES OF STORM WATER TREATMENT.

Date	Details *re* Quantities Dealt with: Total flow of Sewage. (Gallons.)	Excess flow (Gallons.)	Net flow to be dealt with. (Gallons.)	Total Quantity filtered. (Gallons).	Particulars of Filtration: Quantity on Series I. (Gallons.)	Quantity on Series II. (Gallons.)	Quantity on Storm Beds (Gallons.)	Composition of Sewage and Effluents. Oxygen Absorption—4 hours. (Grains per Gallon.): Raw Sewage. Average.	Unfiltered Tank Effluent.	Series I.	Series II.	Storm Beds. Con-tact.	Storm Beds. Bell-mouth.	Albuminoid Ammonia. (Grains per gallon.): Raw Sewage.	Unfiltered Tank Effluent.	Series I.	Series II.	Storm Beds. Con-tact.	Storm Beds. Bell-mouth.	Average Composition of Total Effluent: Oxygen Absorption 4 hours.	Albuminoid Ammonia.	Hours discharging over Bell-mouth.
1903. October 8th	95,362,000	2,377,000	92,985,000	33,602,000	16,460,000	4,230,000	12,912,000	3·72	3·52	1·08	1·00	0·40	0·46	·26	·25	·07	·06	·04	·04	2·60	·19	3 E
„ 13th	69,694,000	3,898,000	65,796,000	22,071,000	12,640,000	3,920,000	5,511,000	5·56	3·64	1·22	1·14	0·44	—	·35	·21	·10	·09	·04	—	2·89	·17	—
„ 14th	89,846,000	6,798,000	83,048,000	37,246,000	11,460,000	3,770,000	22,016,000	3·96	2·60	1·33	1·22	0·90	0·90	·21	·14	·11	·10	·07	·07	1·94	·12	3 T
„ 19th	70,938,000	1,578,000	69,360,000	21,224,000	7,840,000	2,200,000	11,184,000	4·60	3·36	1·13	0·70	0·60	—	·21	·18	·09	·05	·05	—	2·72	·15	—
„ 20th	64,699,000	934,000	63,765,000	21,693,000	11,060,000	3,540,000	7,093,000	5·48	4·72	1·31	1·20	0·59	0·98	·24	·25	·08	·06	·04	·06	3·78	·20	1 W
„ 28th	113,815,000	14,351,000	99,464,000	40,582,000	16,020,000	3,950,000	20,612,000	3·64	3·28	0·93	1·00	0·60	0·45	·28	·13	·06	·06	·02	·02	2·35	·09	3 T
„ 30th	69,782,000	484,000	69,298,000	31,561,000	13,680,000	2,300,000	15,581,000	5·04	4·04	1·55	1·24	1·28	1·67	·24	·22	·06	·06	·06	·09	3·06	·16	1 T
November 2nd	94,818,000	12,386,000	82,432,000	38,286,000	18,660,000	3,060,000	16,566,000	3·84	2·72	0·12	0·82	0·59	0·70	·17	·09	·07	·06	·04	·04	1·87	·08	3 T
„ 16th	37,026,000	—	37,026,000	15,129,000	4,150,000	140,000	10,839,000	7·56	5·24	1·93	—	0·75	—	·46	·31	·12	—	·07	—	3·38	·21	—
„ 23rd	40,388,000	—	40,388,000	15,882,000	4,482,000	1,898,000	9,502,000	7·20	5·08	2·27	2·00	0·68	—	·54	·25	·12	·13	·06	—	3·54	·18	—
„ 26th	74,751,000	—	74,751,000	24,211,000	10,458,000	3,942,000	9,811,000	5·56	3·88	1·41	1·32	0·55	0·82	·25	·23	·11	·12	·04	·05	2·94	·18	1 E
„ 27th	65,136,000	—	65,136,000	19,379,000	7,470,000	3,650,000	8,259,000	6·64	4·72	1·63	1·52	0·70	0·98	·34	·28	·12	·12	·05	·07	3·76	·23	1 E
„ 28th	96,298,000	2,660,000	93,638,000	41,327,000	17,098,000	3,942,000	20,287,000	4·28	3·04	1·03	0·96	0·60	0·56	·15	·12	·06	·04	·04	·05	2·02	·09	2 E
„ 30th	39,096,000	—	39,096,000	14,371,000	5,312,000	2,190,000	6,869,000	6·16	4·36	1·34	1·40	0·56	—	·32	·23	·09	·12	·05	—	3·11	·17	—
December 9th	53,014,000	740,000	52,274,000	36,926,000	10,790,000	3,212,000	22,924,000	6·20	5·04	1·36	1·30	1·19	1·33	·26	·17	·10	·07	·06	·06	2·32	·09	3 T
1904. January 13th	75,981,000	3,536,000	72,445,000	40,586,000	19,588,000	4,340,000	16,658,000	6·08	2·40	1·26	1·16	0·85	0·92	·22	·21	·06	·05	·03	·03	1·67	·12	1 T
February 4th	80,866,000	740,000	80,126,000	50,686,000	24,070,000	4,620,000	21,996,000	5·56	5·20	1·50	1·40	0·89	0·91	·21	·18	·09	·10	·05	·05	2·73	·11	2 T
„ 8th	56,423,000	—	56,423,000	41,669,000	20,584,000	4,060,000	17,025,000	4·84	4·88	1·40	1·46	1·44	1·05	·26	·18	·08	·09	·07	·07	2·30	·10	2 E 1 W
„ 9th	40,430,000	—	40,430,000	32,055,000	16,434,000	4,200,000	11,421,000	7·24	6·76	2·07	1·54	1·30	—	·36	·26	·10	·09	·09	—	2·72	·13	—
„ 20th	59,453,000	—	59,453,000	35,513,000	17,430,000	4,200,000	13,883,000	5·56	3·32	1·02	0·96	1·03	—	·11	·11	·04	·04	·02	—	1·94	·06	—
„ 22nd	40,653,000	—	40,653,000	29,142,000	11,288,000	2,240,000	15,614,000	6·64	2·84	1·62	1·40	0·62	—	·16	·09	·05	·04	·02	—	1·51	·05	—
March 14th	62,468,000	—	62,468,000	52,019,000	16,463,000	3,312,000	32,244,000	6·64	5·64	2·07	1·82	1·72	1·88	·26	·10	·05	·06	·04	·05	2·42	·05	3½ E 4 W
„ 30th	63,144,000	—	63,144,000	35,457,000	16,626,000	4,554,000	14,267,000	7·60	5·12	1·83	1·78	1·21	—	·36	·23	·07	·08	·04	—	3·17	·14	—

(98.) Storm Water Filters (*continued*).

25032 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): Experienee for four years of the working of storm filters on a large scale is that the purification effected is most irregular and out of all proportion to the cost incurred.

6130 *Messrs. Willcox and Raikes*: Storm water filters which are only used occasionally merely act as strainers. For this purpose a fine shallow bed is better and less costly than a deep coarse one. Regard storm water filters, however, as inefficient (26242).

STORM WATER FILTERS.

(99.) DO STORM WATER FILTERS LOSE ANY OF THEIR EFFICIENCY THROUGH BEING USED ONLY INTERMITTENTLY AT LONG INTERVALS.

Fifth Report: Appendix I.

20804 *Messrs. Raymond Ross & Pickles (Burnley)*: Find that unless their storm beds have at least three fillings per week they do not work satisfactorily.

21195-6 *Mr. Bolton (Heywood)*: The action of their storm water filters is more mechanical than chemical, and their efficiency is not affected by long intervals of rest.

21489 *Mr. Kershaw (Rotherham)*: Judging from experience of contact beds, would suppose that storm filters would only act as strainers if used at long intervals.

21706 *Mr. Campbell (Huddersfield)*: Yes; better to apply weak night sewage at fixed periods.

22846 *Mr. Fowler (Manchester)*: If once thoroughly matured, long resting period might be allowed without detriment. It is necessary, however, in the early stages to work the beds up in dry weather.

23507 *Mr. Wike (Sheffield)*: Storm beds must be kept fed to be of any use for bacteriological treatment.

24432 (p. 579) *Dr. Reid*: No practical experience of storm filters; but, judging from results of ordinary filters after long rest, thinks the first effluent from storm filters after long rest would be of good quality.

25033 *Messrs. Watson & O'Shaughnessy (Birmingham)*: Storm water filters probably only act as strainers, and their efficiency would not in that case be affected by long rests.

26242 *Messrs. Willcox & Raikes*: The fact that storm water filters are only used occasionally renders them inefficient.

(100.) DISPOSAL OF SLUDGE.

Interim Report : Vol. II. (*Cd.* 686), 1902.

625 *Mr. Santo Crimp* : Where the population is 5,000 or more, and the sludge is removed by chemical precipitation, filter presses should be used for pressing the sludge. In cases where the quantity of sludge produced is very large indeed, the most satisfactory way of disposing of it is to send it out to sea, if practicable.

Sludge lagoons result in a great nuisance, if the quantity of sludge is at all large.

Sludge has very little manurial value, and it is difficult to get rid of it to farmers.

836–59 *Alderman Hibbert* : At Chorley a portion of the pressed sludge is used for making gas which lights up the sewage works. When coal is at 15s. 6d. per ton, the utilisation of sludge in this way is profitable.

Remainder of sludge is readily disposed of to farmers at 9d. per one-horse load, and 1s. per two-horse load. (The sludge is produced by chemical precipitation.)

Third Report : Vol. II. (*Cd.* 1487), 1903.

3303 *Mr. F. Purcell* : Describes a method of distillation for obtaining from sewage sludge, oil, ammonia (as ammonia water), and a solid residue which can be converted into cement. Results of great numbers of experiments both in the laboratory and on a large scale are as follows :—

Wet Cake from	Ammonia Sulphate.	Residue.	Oil per ton.	Water.
Cross Ness - -	57·56 lbs per ton	39·00 per cent.	7 to 11 gallons	54·10
Leyton - - -	59·80 „ „	68·40 „	9 to 10 „	52·00
Wimbledon - -	65·63 „ „	56·00 „	5 „	51·00

Working with a very imperfect apparatus, and taking the value of the products at a low figure, the experiments seemed to show a profit of 6s. 6d. per ton of sludge dealt with by this method of distillation.

Fifth Report : Appendix I.

0805 *Messrs. Raymond Ross & Pickles* (*Burnley*) : Screenings are dug into adjoining market garden land at Burnley. Practical way of dealing with tank sludge for inland towns is to press it ready for disposal according to circumstances.

SLUDGE. (100.) Disposal of Sludge (*continued*).

21197 *Mr. Bolton* (*Heywood*): Screening refuse should be burned in destructor. Material from detritus tanks may be tipped on land.

Precipitation tank sludge should be pressed, and either burned or used as manure.

Septic tank sludge should be pressed and burned. (Actual experience of burning septic tank cake: 21351–4.)

21490–1 *Mr. Kershaw* (*Rotherham*): Sewage screenings should be burnt in destructor or dug into land.

Detritus tank material can be tipped on land.

Sludge from tanks should be pressed and disposed of to farmers, as far as possible.

Pressed cake and sludge containing lime, when tipped in a heap, is likely to cause a nuisance.

Does not find that sludge lagoons cause nuisance

21706* *Mr. Campbell* (*Huddersfield*): Sewage screenings should be tipped or burnt. Detritus tank material, tipped. Sludge from tanks, deposited in lagoons. If sludge has any manurial value it should be pressed and sold.

21800–2 Quite practicable to burn pressed sludge without causing nuisance, but cost is somewhat heavy. Sludge must be mixed with some fuel (21916).

22484 *Mr. Valentine* (*Oldham*): Suggests that it would be profitable to adopt some system for removing fatty acid and other constituents from sludge. Under present conditions, the entire cost of dealing with sludge in most towns is a dead loss. At Oldham the cost is £1,400 per annum at least.

22847 *Mr. Fowler* (*Manchester*): Sewage screenings should be burnt in destructor; material from detritus tanks can be tipped; sludge from tanks should be dug into land wherever practicable.

23262 *Mr. Carter Bell* (*Salford*): At Salford, all sludge can be cheaply disposed of by shipping to sea. In other circumstances, he would advise the use of destructor furnaces.

23587 *Mr. Wike* (*Sheffield*): Where quantity of sludge is very large, a properly managed tip seems the best way of disposing of it.

23872–7 Doubts the practicability of burning sludge, and thinks that pressing is a costly and difficult process.

2 (p. 579) *Dr. Reid*: Sewage screenings and detritus tank material can be disposed of satisfactorily by frequent removal and disposal on land by digging it in, even where only a small area of land is available.

Sludge from precipitation and sedimentation tanks must be pressed and removed at frequent intervals.

Septic tank sludge can be safely spread on land even in close proximity to dwellings, as it is remarkably free from smell.

There is considerable nuisance from discharging sludge into lagoons.

4 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): Sewage screenings: Burnt in destructor or dug into land within twenty-four hours.

Detritus tank material: Tipped on land.

Precipitation and settlement tank sludge; Dug into land.

Septic tank sludge: Tipped on land

4–6 *Mr. G. Watson* (*Horsfall Destructor Company*): Practicable to burn sewage sludge when mixed with town refuse in proportion, say, of one of sludge to two of refuse by weight. Sludge cannot be burnt alone.

1 No nuisance in burning sewage sludge and town refuse.

4 Probable cost of upkeep of installation, 1s. 6d. per ton burnt.

51 Some return can be secured by using the steam generated, if there is any need for it at the works.

78–80 Sludge must first be pressed or air-dried.

90 seq. *Mr. W. F. Goodrich* (*Meldrum Bros., Ltd.*): Evidence agrees in all essentials with that given by Mr. G. Watson.

31 *Messrs. Willcox & Raikes*: Screenings should be burnt or buried. Sludge from tanks can be conveniently dug into ground if sufficient space is available, or it can be pressed and accumulated or given away as manure.

32 The drying of sludge on surface of land is very likely to cause a nuisance, especially in hot weather.

EFFLUENTS.

(101.) WHAT CONSTITUTES A GOOD EFFLUENT.

Interim Report: Vol. II. (Cd. 686), 1902.

page 204 *Sir H. Roscoe*: Suggested to Mersey and Irwell Joint Committee the following limits of impurity for effluents :—

	Limit.
1. Oxygen absorbed test, permanganate of potash in acid solution, four hours' test at 60° F.	1 grain oxygen per gallon.
2. Oxygen absorbed test, permanganate of potash in acid solution, three minutes' test	$\frac{1}{4}$,, ,, ,, ,,
3. Albuminoid ammonia	$\frac{1}{10}$,, ammonia ,, ,,

3848 *Mr. Dibdin*: A good effluent is one that does not putrefy, and can sustain fish life.

5993-4 *Mr. F. Scudder*: Inclined to define a non-polluting sewage effluent as one capable of absorbing from an acid solution of permanganate of potash at 60° F. not more than 0.5 grain of oxygen per gallon (*i.e.*, half the Mersey and Irwell standard). Three minute oxygen absorbed and the albuminoid ammonia figures to remain the same as stated by Sir H. Roscoe (*see* above). Further, the effluent should be incapable of absorbing more than 2 grains of dissolved oxygen per gallon of effluent from aerated water (1 volume of effluent mixed with 9 volumes of tap water) at 75° F. acting for forty-eight hours, and it should not appreciably destroy nitrates when these are added during a period of incubation for forty-eight hours at 75°F.

9090-2 *Dr. Hill*: A satisfactory effluent would be one which is clear and remains clear without any signs of putrefaction or change in colour or appearance after standing for some days. Effluents that do not putrefy nearly always contain nitrates.

Fifth Report: Appendix I.

20806* *Messrs. Raymond Ross & Pickles (Burnley)*: Consider hat the following factors are requisite for a good effluent :—

(1) That it does not contain any appreciable quantity of suspended matter.
(2) That it is non-putrescible under ordinary climatic conditions.
(3) That it does not deposit sediment on standing.
(4) That it contains sufficient dissolved oxygen to support fish life.
(5) That it contains sufficient nitric nitrogen to deal with organic matter remaining in it.

21199 *Mr. Bolton (Heywood)*: A good effluent is one which—

(*a*) Will not absorb more than ·7 parts per 100,000 of oxygen from permanganate in four hours.
(*b*) Does not contain more than ·07 parts per 100,000 of albuminoid nitrogen.
(*c*) Will not undergo secondary decomposition when incubated at 80°F. for five days.
(*d*) Will not destroy more than its own volume of ærated tap water when incubated at 80°F. for forty-eight hours.
(*e*) Contains an abundance of nitric nitrogen.

Mr. Kershaw (*Rotherham*): One that is not offensive in appearance or smell, and is not liable, when discharged into stream, to become changed in appearance or smell. Nitrates should be present, and the effluent should not yield more than ·1 to ·15 parts Alb. ammonia per 100,000, nor absorb more than 1 to 1·5 parts oxygen in the four hours' test. Should not become putrescent or offensive on keeping and should be free from suspended matter.

Mr. Campbell (*Huddersfield*): One that will remain sweet in incubator for a week in the absence of air.

Mr. Harrison (*Leeds*):

(*a*) It must be non-putrescent.
(*b*) The free ammonia value must be low and the nitric nitrogen value high.
(*c*) The suspended matter must be low.

Mr. Valentine (*Oldham*): Judging from his experience at Oldham, a good effluent generally should, in appearance, be fairly bright and clear, and, if there is any smell, it should be a pleasant earthy one. Such an effluent will generally stand the incubator test which is the ultimate one. An effluent should not be judged according to a fixed oxygen absorbed figure. If that test is relied on, the percentage purification should be the determining factor (say 60–65 per cent. purification on the tank effluent).

Mr. Fowler (*Manchester*): A good effluent—

(*a*) Does not cause deposit in stream;
(*b*) Does not deprive stream of oxygen;
(*c*) Does not encourage weeds or fungus
(*d*) Does not contain pathogenic germs;
(*e*) Is not injurious to fish, plants, or living organisms.

Mr. Carter Bell (*Salford*): One that does not undergo secondary decomposition, and that will not injure the stream.

Mr. Wike (*Sheffield*): Speaking generally, as an engineer, considers that an effluent should be non-putrefactive and not of a character to affect injuriously the stream into which it is passed.

Mr. Haworth (*Sheffield*): An effluent conforming to the provisional standard of the Mersey and Irwell Committee for oxygen absorbed in four hours and albuminoid ammonia. Effluent should not contain more than 5 parts per 100,000 of suspended solids. or absorb a large quantity of dissolved oxygen from well-ærated water.

(101.) What Constitutes a Good Effluent (*continued*).

25036 *Messrs. Watson & O'Shaughnessy* (*Birmingham*):

(1) It should be non-putrescible.
(2) "Albuminoid ammonia" figure should not exceed ·20 parts per 100,000; and the "oxygen absorbed in four hours" should not exceed 2·00 parts per 100,000.
(3) It should not absorb "dissolved oxygen" at an excessive rate.
(4) Mineral suspended matter should not exceed 1 to 1·5 parts per 100,000, and the organic matter 1·0 to 1·5 parts per 100,000.
(5) Clarified effluent should not deposit more than 1–2 parts per 100,000 of solids from solution in (say) twenty-four hours.

26133 *Messrs. Willcox & Raikes*: No effluent which gives more than ·05 parts per 100,000 of albuminoid ammonia and ·27 parts per 100,000 oxygen absorbed in four hours at 80° F. can be considered entirely satisfactory.

(102.) IS THE TYPE OF EFFLUENT FROM A CONTACT BED SUPERIOR OR INFERIOR TO THE TYPE OF EFFLUENT FROM A PERCOLATING FILTER.

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Colonel Harding : Percolating bed filtrates are superior in that they contain more nitrates and more dissolved oxygen.

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Messrs. Raymond Ross & Pickles (Burnley) : Contact bed effluent is superior because :—

(*a*) It is not so liable to deposit on standing or dilution.
(*b*) Organic matter is less putrescible.
(*c*) Purification of strong sewage by double contact is considerably greater.
(*d*) The prolonged contact is probably more inimical to pathogenic organisms.

No experience of percolating filters. The above views are based on paper read by Mr. Fowler as to results at Burnley and Accrington, and upon analyses of percolating bed filtrates supplied by others (21048–52).

Mr. Bolton (Heywood) : Percolating filter effluent is of better type than contact bed effluent : general impurities are less, effluent better ærated and better nitrated, suspended solids settle more readily, and effluent is less liable to undergo secondary decomposition.

Mr. Kershaw (Rotherham) : Insufficient experience to express a definite opinion. Percolating filters appear to produce better nitrification than contact beds.

Mr. Campbell (Huddersfield) : Contact bed effluent is of inferior type. Nitrification is more active in percolating bed, and there is better aeration.

Mr. Harrison (Leeds) : Very little difference under best conditions. Under worst conditions—both filters treating crude sewage—percolating bed filtrate, after settlement, is much the better.

Mr. Valentine (Oldham) : Has had very slight experience of percolating beds ; but thinks that, if the abnormal amount of suspended matter be removed, the percolating bed filtrate would be of a more satisfactory character than a contact bed filtrate.

Mr. Fowler (Manchester) : Double contact bed effluent generally superior ; but there is little difference if percolating filtrate is strained through fine material, though double contact effluent is possibly more broken down.

EFFLUENTS.

(102.) Is the type of Effluent from a Contact Bed superior or inferior to the type of Effluent from a Percolating Filter (*continued*).

23790 *Mr. Wike (Sheffield)*: In the matter of suspended solids, considers that contact bed effluent is superior.

23623 *Mr. Haworth (Sheffield)*: Not much experience of percolating filter effluent, but effluents like those from Sheffield contact beds usually contain less suspended matter than percolating bed filtrates, are rich in nitrates, not putrescible, hold dissolved oxygen, and support fish life.

24432 (p.579) *Dr Reid*: Contact bed effluent is inferior to an effluent from a percolating filter formed of small particless Not so sure that there is so much difference if comparison is made with an effluent from a filter formed of large-size particles.

25037 *Messrs. Watson & O'Shaughnessy (Birmingham)*: A contact bed, by reason of the nature of the conditions, is more effective in eliminating the objectionable constituents of sewage.

But it is comparatively an easy matter to construct a percolating bed to produce any desired result, and there is no reason why the effluent obtained should differ materially from that of a contact bed.

25759-80 *Mr. F. Scudder*: Percolating filtrate is fully oxidised and rich in nitrates. A contact bed effluent is not so highly oxidised. The percolating filtrate will also maintain more dissolved oxygen.

(103.) WHAT TEST OR TESTS ARE CHIEFLY RELIED UPON IN JUDGING OF THE QUALITY OF AN EFFLUENT. EFFLUENTS.

Interim Report: Vol. II. (Cd. 686) 1902.

-4 *Mr. W. Naylor*: Relies on albuminoid ammonia test.

0 *Mr. Santo Crimp*: Would rather rely on absence of sewage fungus and presence of green confervæ in outfall channel as a test than on chemical analysis.

2 *Sir E. Frankland*: Test employed by him for thirty years is the determination of organic carbon and organic nitrogen.

ge 203 *Sir H. Roscoe*: Considers that purely chemical analysis is sufficient to afford a safe criterion as to fitness of sewage effluent to be discharged into a watercourse (non-drinking water stream).

Main tests applied are :—

Estimation of—

1. Free and saline ammonia.
2. Albuminoid ammonia.
3. Oxygen absorbed from permanganate of potash in acid solution acting for three minutes at 60° F.
4. Oxygen absorbed from permanganate of potash in acid solution acting for four hours at 60° F.
5. Nitrites and Nitrates.
6. Incubator test.

18-9 Considers that in 999 cases out of 1,000 these tests give sufficiently accurate results.

46 *Mr. F. W. Stoddart*: His conclusions are based on the proportionate reduction of organic matter as ascertained by oxygen absorbed and albuminoid ammonia tests, the formation of nitrates, and, to some extent, the amount of dissolved oxygen.

56
934-7 *Mr. F. Scudder*: Permanganate process, *i.e.*, estimation of oxygen absorbed from permanganate of potash acting for three minutes and four hours, respectively, at 60° F.

3-6
3-6 But it is desirable to have as many tests as possible, having regard to the possibility of tests being frustrated—*e.g.*, the permanganate test by the use of antiseptics.

EFFLUENTS.

(103.) WHAT TEST OR TESTS ARE CHIEFLY RELIED UPON IN JUDGING OF THE QUALITY OF AN EFFLUENT (*continued*).

7403 *Colonel Harding*: Test of ability of coarse fish to live and thrive in an effluent is valuable evidence of presence of dissolved oxygen and absence of much impurity. Character of growth in outflow basins and in channels through which effluents and filtrates pass also an obvious general test of character of effluent.

8947-8 *Dr. Thresh*: Incubator test generally relied upon. This is a test of the putrescibility of an effluent.

8953 Freedom from colour and odour a sufficient general test as a rule.

10240-1 *Dr. Voelcker*: Generally estimates matter in suspension and the nature of it—whether organic or inorganic. Also examines filtered material, determining solids, lime, magnesia, sulphuric acid, nitric, chlorine, and silica. In addition to these makes determinations of amount of oxgyen absorbed from permanganate, free ammonia, and albuminoid ammonia, and also the amount of aeration.

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20603 *Dr. Reid*: Uses the free and albuminoid ammonia tests, the oxygen absorbed in 4 hours at 80° F., the nitrate nitrogen, and estimates the solids in suspension and in solution and the chlorine. Has also in Staffordshire a standard of opacity.

20807 *Messrs. Raymond Ross & Pickles* (*Burnley*):

(1) Amount of probably putrescible matter as measured by the albuminoid ammonia and oxygen absorbed tests.
(2) Total purification as measured from the improvement effected on the albuminoid ammonia.
(3) Amount of nitrification effected and the condition of the nitrogen.
(4) Rapidity of absorption of dissolved oxygen.
(5) Amount of suspended matter and proportion of organic to inorganic.

21201 *Mr. Bolton* (*Heywood*): Chiefly relies on oxygen absorbed from permanganate figures, three minutes and four hours, and albuminoid nitrogen.

21404 *Mr. Kershaw* (*Rotherham*): Four hours' oxygen absorption at laboratory temperature as a routine test Nitrate and alb. ammonia determinations are also made.

(103.) What Test or Tests are chiefly relied upon in judging of the quality of an Effluent (*continued*). EFFLUENTS.

1709 *Mr. Campbell* (*Huddersfield*):

(1) Incubator test.
(2) Oxidised nitrogen.
(3) Albuminoid nitrogen.
(4) Oxygen absorbed.

2044 *Mr. Harrison* (*Leeds*): The most reliable method of testing the putrescibility of an effluent is the "aeration test." A really good effluent will not absorb more than 25 per cent. of its dissolved oxygen, and a moderate effluent from 30 to 40 per cent.

The free ammonia test is also very useful, for generally any effluent containing only a small quantity will be stable with regard to the "aeration test."

The "oxygen absorbed" and albuminoid ammonia tests give very parallel results with any particular sewage.

22851 *Mr. Fowler* (*Manchester*): Primarily, the "aeration test." This is generally sufficient; but, as a further precaution, the incubation test should be applied, and the amount of suspended matter under these conditions noted.

23265 *Mr. Carter Bell* (*Salford*): Oxygen absorbed from permanganate in four hours, and incubation for seven days from 70° F. to 90° F.

23591 *Mr. Wike* (*Sheffield*): Putrescibility, most important test, in his opinion. Not a chemist.

23624 *Mr. Haworth* (*Sheffield*): Oxygen absorbed in four hours and the free and albuminoid ammonia, and nitrogen as nitrates and nitrites. These are confirmed by incubator test and "aeration test" For frequent checking of quality of effluents, the oxygen absorbed in four hours, incubator, and nitrate tests, are convenient and reliable.

25038 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): Rely chiefly on the following tests:—

(1) Suspended solids.
(2) Albuminoid ammonia.
(3) Oxygen absorbed.
(4) Three minutes' test before and after incubation.
(5) Nitrification.

EFFLU-
ENTS

(103.) WHAT TEST OR TESTS ARE CHIEFLY RELIED UPON IN JUDGING OF THE QUALITY OF AN EFFLUENT (*continued*).

25578 *Dr. W. E. Adeney*: Numerous experiments show that the adoption of the aeration method of analysis is a necessity for the estimation of the quality of a sewage effluent.

26135 *Messrs. Willcox & Raikes*: Oxygen absorbed is the most convenient test and affords the best guide to the quality of effluent, as it is a direct index of organic impurity.

(104.) IS ONE STANDARD FOR ALL EFFLUENTS PASSING INTO NON-POTABLE STREAMS POSSIBLE AND DESIRABLE. STAND-ARDS.

Interim Report: Vol. II. (Cd. 686), 1902.

85 *Mr. F. Scudder*: Reasons for not adopting standard (Sir Henry Roscoe: *see also* 203–4): (1) Conditions of stream vary with time of year; (2) each industry must require a different standard; (3) a standard which would be fair at head of steam, such as the Irwell, would not be fair on same river at Manchester.

08–716 Would not so much object to standard test if it was only to be used by qualified chemist.

088–97 Would recommend the adoption of the Mersey and Irwell standards as provisional standards for
033 the whole country. Would not advocate rigid application of those standards. In fixing standards it is very important to describe exactly how the tests are to be carried out.

16 *Mr. Naylor*: Sees no reasonable objection to a standard and thinks it would have many advantages.

196–9 *Dr. Maclean Wilson*: Impossible to fix standards. Not desirable to have a fixed standard, as
364–7) amount of purification necessary would vary according to circumstances.

Has adopted the Mersey and Irwell limits of impurity for working tests.

533–4 *Dr. Theodore Thomson*: Effluent good according to analysis may foul the stream. Again, an effluent may cause no nuisance in one stream, but a great nuisance in another.

312 *Mr. W. S. Curphey*: Disagrees with fixed standards for same reasons as Dr. Maclean Wilson.

Making a standard sets up a limit beyond which advance is discouraged. A standard now complied with with difficulty, may with improved methods become a very low standard indeed.

426 *Dr. Adeney*: Not desirable to have hard and fast standard. It should vary with local circumstances A standard might be formulated upon the quantity of atmospheric oxygen which any effluent or sewage will absorb during its complete conversion into a harmless condition (2428–9).

422–6 In cases of small towns and villages, it would be sufficient if the effluent when mixed with stream will not putrefy or set up putrefaction.

age 204 *Sir H. Roscoe*: Impossible to fix definite standards. The application of the best practicable means of
670–3684) treatment would bring any effluent below limits of impurity adopted by Mersey and Irwell Committee.

54 *Dr. Barwise*: Desirable that Commission should suggest a standard, even if it were not made a hard and fast one. Suggests following limits:—

	Parts per 100,000.
Suspended matter not more than	3
Oxygen absorbed in 4 hours at 80° F. not more than	1·5
Albuminoid ammonia not more than	·1 to ·15
Nitrogen as nitrates at least	·2

STAND-ARDS.

(104.) IS ONE STANDARD FOR ALL EFFLUENTS PASSING INTO NON-POTABLE STREAMS POSSIBLE AND DESIRABLE (*continued*).

503 *Mr. F. W. Stoddart*: A proportionate reduction in impurities rather than reduction to an absolute fixed amount is the proper kind of standard to adopt.

557-8 *Mr. G. R. Strachan*: Objects strongly to fixed standard. The destination of the sewage or effluent must govern the amount of purification required, *i.e.*, it must not cause nuisance, injury, or annoyance in the river into which it goes. His standard would vary with volume of river not with its condition (7597-8).

7889-94 *Alderman Hibbert*: Would have one standard for all sewage works in Lancashire.

9819 (12) *Dr. Williams*: Uniform standard not practicable, local circumstances differing so much.

Third Report: Vol. II. (*Cd.* 1487), 1903.

12166 *Mr. A. E. Fletcher*: Strongly of opinion that the requirement of " best practicable means " of treatment is preferable to fixed standard.

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20809 *Messrs. Raymond Ross & Pickles*: No.

21203 *Mr. Bolton* (*Heywood*): A general standard is desirable.

21496 *Mr. Kershaw* (*Rotherham*): No.

20616 *Dr. Reid*: A standard would be convenient, but a uniform standard would seem to be impracticable. Any standard which may be laid down should apply only to zones, as the varying characteristics of different districts must be taken into account.

(104.) Is one Standard for all Effluents passing into non-potable Streams possible and desirable (*continued*). STANDARDS.

21711 *Mr. Campbell* (*Huddersfield*): Yes, but not a chemical standard. Suggests that "effluent should be such that a sample would keep without putrefying for some days at a temperature of 80°F. in tightly-stoppered bottle."

22044 *Mr. Harrison* (*Leeds*): Not in favour of fixed standards of purity based upon numerical values, for the reason that different processes, even when the same liquid is treated, produce effluents containing varying amounts of organic impurity, as determined by the usual tests, the quantity of which is no safe criterion of the power an effluent possesses of resisting putrefactive changes.

For example he has found that the highest oxygen absorbed figure (4 hours test) for a non-putrescent double contact bed effluent has been 1·62 parts per 100,000; but a continuous filter treating crude sewage gave non-putrescent effluents having a value as high as 2·30.

22487 *Mr. Valentine* (*Oldham*): Thinks not.

22852 *Mr. Fowler* (*Manchester*): No.

23267 *Mr. Carter Bell* (*Salford*): Yes, standard adopted by Mersey and Irwell Joint Committee a good and desirable one.

23592 *Mr. Wike* (*Sheffield*): No.

25040 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): No.

25715 *Mr. F. Scudder*: Not in favour of hard and fast standards.

26136 *Messrs. Willcox & Raikes*: Different standards required for different watersheds but all might have certain points in common, such as absence of suspended matter and the amount of oxygen absorbed.

26248-9 Main points to be considered in classification of rivers and streams are :—

(*a*) Characteristics of watershed.
(*b*) Measurement of quantity and quality.
(*c*) Methods of measurement.
(*d*) Causes of pollution.
(*e*) Interests affected by pollution.

STAND-ARDS.

(105.) HOW SHOULD A PLURALITY OR SERIES OF STANDARDS BE FORMULATED. WHAT AMOUNT OF SUSPENDED MATTER SHOULD BE ALLOWED IN AN EFFLUENT.

Interim Report : Vol. II. (Cd. 686), 1902.

916 *Mr. Naylor* : Thinks all manufacturers can reduce matter in suspension below 3 parts per 100,000.

1367 *Dr. Maclean Wilson* : If any standard is decided upon, it must be one showing amount of purification as judged from the nitrates and, what is more important, the effect of the effluent on the stream.

4160 *Dr. S. Rideal* : Criticises the various standards which have been proposed for sewage effluents, and expresses opinion that *the quality of the stream* and not of the effluent should be taken as the basis.

4161 Suggests formulæ for a practical standard, based on conditions of free and potential oxygen.

5078–9 *Mr. F. Scudder* : Would limit the amount of suspended solids to a maximum of 3 grains per gallon. Conclusion after examining large number of samples (5980).

10049 *Dr. P. F. Frankland* : Suggests that the condition of the stream into which the effluent is discharged must be taken into account. Except where the stream is exceptionally pure, effluent ought not to be of worse quality than the water in the stream.

Fifth Report : Appendix I.

20810 *Messrs. Raymond Ross & Pickles* (*Burnley*) : Standards which would take into consideration strength and volume of the sewage and velocity and volume of the stream. These to be adopted by mutual arrangement between local authorities and Rivers Board, and, in case of dispute, settled by Central Authority.

21203 *Mr. Bolton* (*Heywood*) : Suggests following standard :—

Oxygen absorbed from permanganate in 4 hours	1·50	parts per 100,000.
Albuminoid nitrogen	·12	,,

Non-putrescible when incubated for five days at 80° F.
Not to destroy more than 2 volumes of aerated tap water when incubated at 80° F. for 48 hours.
Nitric nitrogen present.
Organic solids in suspension not more than 1·5 parts per 100,000.

21497 *Mr. Kershaw* (*Rotherham*) : A combined standard of, say, ·15 parts alb. N. ammonia, or 1.5 parts oxygen (parts per 100,000) absorbed in 4 hours, in addition to presence of nitrates. Suspended matter, 2 to 3 parts per 100,000 might be allowed.

(105.) How Should a Plurality or Series of Standards be Formulated. What Amount of Suspended Matter Should be Allowed in an Effluent (*continued*). STAND-ARDS.

1712 *Mr. Campbell* (*Huddersfield*): If general standards are impracticable local standards should be made, In fixing which, following should be taken into account:—

(1) Character of stream receiving effluent.
(2) Nature of sewage and difficulty of its treatment.
Not more than 5 parts per 100,000 of suspended solids should be allowed.

2044 *Mr. Harrison* (*Leeds*): Not in favour of fixed standards of purity based upon numerical values. A contact bed effluent should not contain more than 3 grains per gallon (4·2 parts per 100,000) of suspended-matter: a continuous bed filtrate may contain up to 5 or 6 parts per 100,000, if the other tests are satisfactory, as the solids in this case are usually better oxidised than in the former.

2488 *Mr. Valentine* (*Oldham*): A plurality or series of standards seems impracticable. Efficient and frequent inspection, with advisory and plenary powers, will probably be the best means of securing efficiency.

From experience at Oldham, thinks that effluents containing less than 5 parts per 100,000 of suspended matter are generally satisfactory.

2853 *Mr. Fowler* (*Manchester*): Each case must be taken on its merits, regard being had to conditions at the point of discharge.

268 *Mr. Carter Bell* (*Salford*): From 1 to 3 parts per 100,000 of suspended matter. (This opinion based on experience in connection with Ship Canal: 23364.)

593 *Mr. Wike* (*Sheffield*): Standard should have some relation to the condition and volume of stream. Central Authority desirable to discriminate between different places.

041 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): Standards must be fixed according to the local conditions of the particular place. Would allow 3 parts per 100,000 of suspended solids in an effluent.

578 *Dr. W. E. Adeney*: Is in favour of standards graduated to meet local circumstances and requirements A question of great practical importance, in the formulation of standards, is the question of the rate of the re-absorption of oxygen by water exposed to natural conditions after it has been de-aerated by admixture with sewage matter. Gives result of some experiments for determining this.

TESTS.

(106.) VALUES ATTACHED TO DIFFERENT CHEMICAL TESTS.

Interim Report: Vol. II. (Cd. 686), 1902.

593 *Mr. F. Scudder*: Permanganate of potash test more likely to give correct information as to quality than any other test. (Can be frustrated by antiseptic treatment 693–7.)

606 Incubator test most valuable one if sewage has been treated bacteriologically. (Statement based upon some 10,000 experiments.)

5951 Total albuminoid ammonia gives some idea of the total organic nitrogen in effluents. Attaches much more importance to the rate at which the albuminoid ammonia is formed (5953).

5955–6 Purely chemical test runs parallel with biological test, and for that reason believes in permanganate process as giving a fair indication.

5988–9 Incubator test is valuable guide, but will not stand too much. Important to take into consideration rate at which nitrates disappear during incubation (5993).

6058 The incubator test, by finding out the loss of nitrates and of dissolved oxygen, is of great value in indicating pollution where sewage has been diluted in order to bring it within chemical standards.

1276–82 *Dr. Maclean Wilson*: Important to estimate quantity of nitrates present or whether nitrates develop on keeping. This is a valuable guide as to the extent to which purification has been carried. Some effluents apparently good according to other tests will subsequently decompose.

1607 *Mr. Santo Crimp*: Chemical analysis cannot be relied upon (25 years' experience.) Effluents good according to analysis sometimes become offensive below the works. This only happens with chemically treated effluents (*see* 1750).

2387 *Dr. Adeney*: Free ammonia determination is valuable as indicating degree of foulness of sewage; and it may indicate in sewage that has been kept whether fermentation is going on or not.

2392–5 Albuminoid ammonia determination in the case of sewages and effluents has no value. It affords no indication whatever of quantity of organic matters in the liquid, seeing that no albuminoid ammonia is yielded by such important fermentable constituents of sewage as urea and non-nitrogenous substances, *e.g.*, soaps, fats, etc.

2398 Essential thing in analysing sewages or effluents is to distinguish between what organic matters are not fermented and what are, and to determine the quantity of the former. Neither albuminoid ammonia nor the permanganate test will enable these distinctions to be made.

2399–2401 Nitrogen estimation is an excellent index of the accuracy with which the analyses have been made. No other significance.

2402–8 Presence of nitrites is an indication that fermentation has not been completed. Nitrates indicate complete purification.

2410 Oxygen absorbed tests quite worthless for giving any exact idea as to character of sewage. The tests do not distinguish between unfermented and fermented organic matters. Again, the permanganate of potash acts slowly upon certain albuminous bodies; it will not oxidise all the organic matter even when added in excess.

2931–2 *Dr. Sims Woodhead*: Absorption of oxygen is a reliable test for general purposes.

2933 Would prefer estimation of nitrates to estimation of albuminoid ammonia.

2972 As a ready method, incubator test is of much greater value than chemical analyses.

3012 (See also 3041–59) *Sir E. Frankland*: Incubator test not always reliable. Some effluents which are highly polluting when turned into running water do not become offensive in bottle.

3019 Oxygen absorbed test, though better than none at all, is fallacious in several ways. There may be reducing agents present which would not be putrefactive in the stream, but which would absorb oxygen from the permanganate.

3021 Albuminoid ammonia test of no value at all, because it yields such very different results with different organic compounds.

3097–9 Considers both albuminoid ammonia and oxygen absorbed tests untrustworthy when used with a mixture of so many and various substances as in a sewage of a town. Albuminoid ammonia the more uncertain.

576 *Sir H. Roscoe*: Oxygen absorption is a means of determining organic matter.

581 Regards determination of albuminoid ammonia as important as showing that oxygen absorption test is not always reliable. Both tests should be taken together.

586–8 Chlorine estimation not of very great importance so far as he is aware. More a measure of the domestic sewage than anything else.

611 Does not think incubator test alone is sufficient. Must in all cases be strengthened and controlled by chemical analysis (free and albuminoid ammonia and oxygen absorbed).

785 Does not consider that testing for nitrates is of essential value.

847–51 *Mr. Dibdin*: Oxygen absorbed and albuminoid ammonia tests are not accurate as measures of the organic matter. Oxygen absorption is more a measure of organic matter in a particular condition.

852–3 Incubator test is not an absolute one. (Has not used it himself.)

4260–1 *Dr. S. Rideal*:

As a general rule, chlorine in sewage is sufficiently constant to make it a basis for statement of analysis. Analyses would be much more readily comparable if they were referred to total chlorine.

4262–6 Estimations of albuminoid ammonia and oxygen absorption of no value by themselves. Albuminoid ammonia test very unsatisfactory and misleading; quantity of albuminoid ammonia in effluent may be well below usual standards and yet the effluent may be of a very dangerous character. Much depends upon its derivation.

4275 Suggests the ratio of nitrate to organic matter, organic nitrogen, as a quick test.

8655–65 *Dr. Letts*: Does not think well of the permanganate tests. As a scientific test, its results are often misleading.
8666 From his experience with Belfast sewage, is inclined to think more highly of albuminoid ammonia test; not much discrepancy between albuminoid ammonia and organic nitrogen.

10042–3 *Dr. P. F. Frankland*: Incubator test of great value.

10044–5 Three minutes oxygen absorption test gives a very rapid indication of what is going on, of what the amount of organic matter is. Suitable test for a workman.

Fifth Report: Appendix I.

Messrs. Raymond Ross & Pickles (Burnley):

20814 Four hours' oxygen test a useful comparative test.

Albuminoid ammonia test still more useful for indicating amount of treatment required (*see also* 21053–6).

Nitrogen determination by Kjeldahl much more satisfactory than albuminoid ammonia

Three minutes' oxygen test is useful indication of amount of trade effluent present.

Dissolved oxygen test greatest possible value for effluents.

Nitrites and nitrates indicate reserve of oxygen and the extent of purification.

TESTS. (106.) Values attached to Different Chemical Tests (*continued*).

Fifth Report: Appendix I.

21207 *Mr. Bolton* (*Heywood*): Attaches most value to oxygen absorbed test from permanganate. Generally harmonises with other tests.

Chlorine test valuable to indicate whether sample of effluent is representative of preceding sample of sewage.

Nitrites and nitrates indicate condition of bed.

Albuminoid nitrogen affords clue to putrescible matter.

"Aeration test" of great importance, as indicating the effect the effluent will have on river.

Secondary decomposition test important, as it shows whether effluent will give rise to nuisance through developing offensive odours.

21716 *Mr. Campbell* (*Huddersfield*): Chlorine generally good guide to strength of sewage, though local conditions must be taken into account.

Albuminoid nitrogen and oxygen absorbed tests give fairly good indication of substances destroyed. These two should be done side by side.

For effluents, incubation test the most valuable. Next in importance is oxidised nitrogen, as this indicates working condition of bed. Oxygen absorbed in four hours along with three minutes' test valuable indication of oxidation. Albuminoid nitrogen also good test of purity.

22044 *Mr. Harrison* (*Leeds*): Oxygen absorbed tests (four hours and three minutes) are not a safe criterion of the power an effluent possesses of resisting putrefactive changes.

"Aeration test" is most reliable method of determining putrescibility of an effluent.

Free ammonia test is also very useful.

Oxygen absorbed and albuminoid ammonia tests give very parallel results with any particular sewage.

As regards amount of suspended matter, contact bed effluent should not contain more than 4·2 parts per 100,000, and a percolating bed filtrate not more than 5–6 parts per 100,000, if other tests are satisfactory.

Mr. Valentine (*Oldham*):

22484* (*a*) Incubator test. Regards this as the ultimate test.

(*b*) Oxygen absorbed in four hours from permanganate: Arbitrary figure undesirable. By this test the effluent should be judged according to percentage purification (say 60–65 per cent. on the tank effluent as indicating a satisfactory degree of purification).

22491 (*c*) Albuminoid nitrogen test: Should be used on the same lines as the oxygen absorbed test, but a percentage of purification of 55 would be sufficient by it.

(*d*) Nitrate test: Not applicable to Oldham sewage.

(*e*) "Dissolved oxygen" test: Higher percentage purification desirable with this test (say 70 per cent.) than with absorption of oxygen test.

22857 *Mr. Fowler* (*Manchester*): Refers to his lecture, "The Application of Chemical Analysis to the Study of the Biological Processes of Sewage Purification," delivered at the Public Health Laboratory at the University of Manchester, March 14th, 1904.

23272 *Mr. Carter Bell* (*Salford*): Considers that oxygen absorbed and albuminoid ammonia tests are quite sufficient.

626 *Mr. Haworth (Sheffield)*:

(1) *Oxygen absorbed in four hours.* Useful in indicating approximately the total work of purification required and general efficiency of result.
(2) *Free and saline, and albuminoid ammonia.* Indicate, in combination with (1) the general character of impurities in sewage and the progress of the purification.
(3) *Nitrogen as nitrates and nitrites.* Indicate efficiency of process, and most valuable as indication of quality of effluent and condition of bed.
(4) *Suspended solids.* Of greatest value, as bearing upon capacity of filters and effects upon streams.
(5) *Incubator test.* Most valuable as determining liability of effluent to putresce.
(6) *Rate of absorption of dissolved oxygen.* Of great value as indicating probable effect upon water of streams.

676–8 Putrescibility test a satisfactory one.

043 *Messrs. Watson & O'Shaughnessy (Birmingham)*:

(1) "Dissolved solids" estimation a very useful and rapid check on general method of purification; it also often readily indicates abnormal conditions of liquid being treated.
(2) "Suspended solids" test of great importance.
(3) "Free ammonia" test is interesting as indicating either the history or condition of sewage.
(4) "Albuminoid ammonia" figure is a most important one, as indicating the relative efficiency of different methods of treatment.
(5) "Nitrification" test indicates the conditions in the filter.
(6) "Oxygen absorbed in four hours at 80°F." perhaps the most useful test.
(7) "Three minutes'" test is a ready means of determining the putrescibility of a liquid.

578 *Dr. Adeney*: Numerous experiments show that the adoption of the aeration method of analysis is a necessity for the estimation of the quality of an effluent.

626 Aeration test when completely carried out can be relied upon: but believes that some additional
6?4–8 tests, as ammonia determinations, or as the permanganate test, are necessary in ordinary practice as a protection against the use of antiseptics.

692 *Mr. F. Scudder*: Dissolved oxygen test very valuable for discriminating between good and bad samples.
6?3 Not so applicable for judging between "fair" and "unsatisfactory" effluents. His conclusion is that any effluent which, when mixed with its own volume of tap water and incubated at 75° for three days, still contained oxygen, would be excellent. That is all the value he places on the test.

6140 *Messrs. Willcox and Raikes*: Oxygen absorbed test is preferable to any other on account of its simplicity.

MISCELLANEOUS

(107.) VIEWS WITH REGARD TO THE QUANTITATIVE DETERMINATION OF THE "STRENGTH" OF A SEWAGE, TANK LIQUOR, ETC.

Fifth Report: Appendix I.

20815 *Messrs. Raymond Ross & Pickles (Burnley)*: (1) CRUDE SEWAGE.

(*a*) Most important points to be determined are the suspended matter, and the ratio of organic to inorganic matter.
(*b*) The saline and organic ammonia should be determined for organic strength.
(*c*) Three minutes oxygen test should be used as an indication of the amount of trade effluent.
(*d*) Determination of amounts of grease and cellulose also useful, and in some cases, absolutely necessary.

(2) TANK LIQUOR.

(*a*) Additional amount of ammonia should be found.
(*b*) Reduced amount of suspended matter.

(3) PRIMARY CONTACT BED EFFLUENT.

(*a*) Decrease in free ammonia of 40–50 per cent., and about the same in albuminoid ammonia.
(*b*) Hydrolysis is requisite, but not nitrification.

(4) SECONDARY CONTACT BED EFFLUENT.

(*a*) Reduction of albuminoid ammonia to lowest point.
(*b*) Oxygen absorbed should be low.
(*c*) Nitric nitrogen high.

21208 *Mr. Bolton (Heywood)*: Suggests the following as indicating strength of sewage, etc:—

Oxygen absorbed (4 hours' test).	Albuminoid nitrogen.	"Strength."
9 and above.	·9 and above.	Strong sewage.
5 to 9.	·5 to ·9.	Fairly strong sewage
5 and under.	·4 and under.	Weak sewage
5 and above.	·4 and above.	Strong tank liquor
3 to 5.	·2 to ·4.	Fairly strong
Under 3.	Under ·2.	Weak tank liquor
(parts per 100,000)	(parts per 100,000)	

21501 *Mr. Kershaw (Rotherham)*: Results of four hours' oxygen absorption and the albuminoid determinations are the two most useful.

21716 *Mr. Campbell (Huddersfield)*: Strength best determined by

Albuminoid nitrogen Oxygen absorbed Solids in suspension.	Indicate strength in matters to be destroyed.
Chlorine	Indicates variations in strength in different weathers.

22492 *Mr. Valentine (Oldham)*: Comparative tests should be instituted setting forth results obtained with the raw sewage, settled sewage, etc. Oxygen absorption, and ammoniacal and albuminoid nitrogen tests give good idea as to "strength."

73 *Mr. Carter Bell* (*Salford*): "According to the amount of chemicals it requires to purify 1,000,000 gallons."

27 *Mr. Haworth* (*Sheffield*): For practical purposes, strength is conveniently and satisfactorily indicated by the oxygen absorbed in four hours, and free, saline, and albuminoid ammonia, and suspended solids determinations.

44 *Messrs. Watson & O'Shaughnessy* (*Birmingham*): In absolute terms, "strength" is represented by the amount of oxygen necessary to completely oxidise the organic impurities in a given unit of volume. For practical purposes, "strength" may be measured by a comparison of the "oxygen absorbed" figure in the liquid under consideration with that of the corresponding figure in an admittedly good effluent.

78 *Dr. W. E. Adeney*: Gives results of certain experiments supporting the view held by him that the adoption of the aeration method of analysis is a necessity for the accurate determination of the "strength" of a sewage or tank liquor, for the estimation of the quality of an effluent, and for the formulation of standards for effluents. These results are confirmed by a large number of other experimental investigations.

What is required to be known is the volume of oxygen absorbed, and, further, if very efficient purification is required, the volume of oxygen absorbed during the fermentation of part or whole of the ammonia remaining in the liquid after the fermentation of the organic substances. Suggests a method by which rapid fermentations can be obtained.

MISCEL-
LANEOUS

(108.) HOW FAR SHOULD A SEWAGE INSTALLATION BE WORKED AUTOMATICALLY.

Fifth Report: Appendix I.

20812 *Messrs. Raymond Ross & Pickles* (*Burnley*): Automatic apparatus not advisable in works of any size, and even in small works frequent supervision would be necessary.

21205 *Mr. Bolton* (*Heywood*): Automatic apparatus an essential feature of percolating filters working intermittently.

21499 *Mr. Kershaw* (*Rotherham*): No sewage works of any dimensions should be worked automatically. Works require constant personal attention.

21714 *Mr. Campbell* (*Huddersfield*): Inadvisable in case of large installations. Sewage treatment can only be properly controlled by careful supervision and frequent tests.

22489 *Mr. Valentine* (*Oldham*): Objects to use of automatic gear in connection with contact beds, as it is not adjustable to variations in flow, strength, etc., of sewage, and is liable to become deranged; manual labour is less expensive and is safer and more reliable.

22855 *Mr. Fowler* (*Manchester*): Automatic working not desirable or useful in large works. Some simple automatic apparatus is often useful in small installations, but more with the object of minimising supervision than dispensing with it altogether.

23270 *Mr. Carter Bell* (*Salford*): "Automatic working is preferable."

23594 *Mr. Wike* (*Sheffield*): Ordinarily, automatic working is not advisable, as its efficiency depends upon a uniform flow and quality of sewage.

24333–4 *Mr. Wilkinson* (*Manchester*): Automatic gear needs personal supervision, and it is only useful for small works where the constant service of even one man cannot be afforded.

(108.) How far should a Sewage Installation be Worked Automatically (*continued*). MISCEL-LANEOUS

24432 (p. 580) *Dr. Reid*: For economical reasons, automatic working as far as possible is advantageous in small works. Not so essential in large works where men are always on the spot. For filters in any case, some form of automatic distributor is needed.

26138 *Messrs. Willcox and Raikes*: Automatic apparatus can only be considered an economical substitute for manual labour, intelligent supervision being essential in either case.

ROYAL COMMISSION ON SEWAGE DISPOSAL.

SUPPLEMENTARY VOLUMES PRESENTED WITH THE

FIFTH REPORT

OF

THE COMMISSIONERS

APPOINTED TO INQUIRE AND REPORT WHAT METHODS OF

Treating and Disposing of Sewage

(Including any Liquid from any Factory or Manufacturing Process)

MAY PROPERLY BE ADOPTED.

Methods of Treating and Disposing of Sewage.

APPENDIX III.

MEMORANDA GIVING THE RESULTS OF OBSERVATIONS (MAINLY DURING 1902–5) ON VARIOUS PROCESSES OF SEWAGE TREATMENT BY

Dr. G. McGOWAN, Dr. A. C. HOUSTON, Mr. C. C. FRYE,
and Mr. G. B. KERSHAW.

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PRINTED FOR HIS MAJESTY'S STATIONERY OFFICE,
By WYMAN & SONS, Limited, 109, Fetter Lane, E.C.

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NAMES OF PLACES AT WHICH OBSERVATIONS WERE MADE.

ROYAL COMMISSION ON SEWAGE DISPOSAL.

APPENDIX III. TO FIFTH REPORT.

Memoranda giving the results of observations on various processes of sewage treatment made for the Commission by Dr. G. McGowan, Dr. A. C. Houston, Mr. C. C. Frye, and Mr. G. B. Kershaw.

The following Appendix contains the results of observations made for the Commission at twenty-seven sewage works and experimental installations within the years 1902–6 (in all but two cases, within 1902–5), together with a few earlier observations at two of the stations. The reports were presented to the Commission some little time after the observations were completed, but their correction for the Press had to be delayed, mainly on account of other work in connection with the Commission's Fifth Report.

The various installations which were under observation covered practically all the main processes of sewage purification by biological filters at the time when the scheme of investigation was projected, and they were in our opinion the best examples of these, for the purposes of observation, though not necessarily the most perfect examples in every case. They included the treatment, in different ways, of strong, medium and weak water-closet and slop-water sewages, often containing a variety of trade refuse, though in no case was the latter present in such quantity as to interfere materially with the working of the process. It should also be stated here that further evidence relating to biological filtration, in connection with various large towns and cities, was collected independently by the Commission from the local chemists and engineers.

The importance of correctly gauging the flow of sewage and of drawing average samples over the twenty-four hours of the day, according to the rate of flow, has already been emphasized in the Commission's recent Report. It is impossible to lay too much stress upon those two points.

When characterizing an effluent as regards quality, we have always referred to the effluent *by itself*, without considering the volume, character, or use of the stream into which it might pass, or any other external circumstances.

As everyone knows, the "oxygen absorbed" from permanganate test—among others—is an empirical one, but calculations of percentage reduction which are based upon it are of considerable practical value, and they have therefore been used throughout this appendix.

The incubation results are sometimes given in words, as "passed" (*i.e.*, was satisfactory) and "failed" (*i.e.*, unsatisfactory), and sometimes in the symbols + and −. The symbol + is used in the same sense as the word "passed," and the symbol − as the word "failed."

The general deductions drawn from these observations have been given in the Fifth Report of the Commission.

We have invariably had every facility afforded us by the Local Authorities, and we cannot sufficiently express our obligations, both to them and to the Officials in charge of the different sewage works.

GEORGE McGOWAN, } *Chemists.*
COLIN C. FRYE, }
A. C. HOUSTON, *Bacteriologist.*
May, 1909. G. B. KERSHAW, *Engineer.*

NOTE BY DR. McGOWAN.

The chemical methods followed in the work of this Appendix have already been fully described in the Fourth Report of the Commission, Vol. IV., Part V. (1904). One or two points bearing on the subject require, however, a short reference:—

Determination of Albuminoid Nitrogen.

In determining "free" and "albuminoid" ammonia, as specified in the above Report, distilled water made from a continuous-feed copper still, without an "anti-spit" tube attached to it, was used, up to near the end of 1905. Such water necessarily contains a small and varying amount of "free" ammonia, and for each bottle of it used a correction has to be made for this, in Nesslerizing (*loc. cit.*, p. 13). Distilled water prepared in this way was eventually found, however, to be sometimes unsatisfactory for the exact estimation of albuminoid ammonia in effluents, because it contained traces of nitrogenous organic matter which had come over either by distilling or by spitting, or both, and also because the "free ammonia" present was not infrequently rather high.

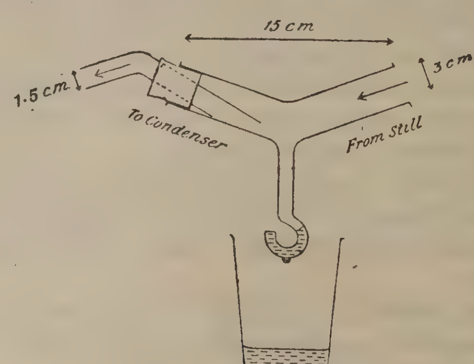
In going over the results of the analyses given in this Appendix, therefore, the figure obtained for albuminoid nitrogen in filter effluents has been nearly always rejected when the "ammonia correction" of the distilled water used was high, relatively to the total

6225.—App. III. 1,250—Wt. 26170. 6/09. Wy. & S.

"albuminoid" ammonia nesslerized,—say, more than 1 : 3 (in the case of sewages and tank liquors the point hardly comes in). This is not entirely satisfactory, as the above ratio may conceivably be high, from the presence in the distilled water of "free ammonia" only, and the albuminoid ammonia determination be right, while the converse might also hold. Still, after consideration of the whole question, including a study of other figures of the analyses, we consider that the figures given for albuminoid nitrogen in the filter effluents, together with any deductions drawn from them, may be taken as substantially correct.

Mr. Scudder's criticism as to the inadvisability of using such continuous-feed distilled water has thus been justified. For some years past we have abandoned its use for this purpose, and have substituted for it water distilled from a glass flask after being slightly acidified with sulphuric acid.

It may be added, however, with regard to continuous-feed distilled water from a copper still, that by interposing between the still and the condenser a rather wide "anti-spit" tube, devised by Mr. A. F. Girvan (see appended figure), the "albuminoid" ammonia in the distilled water obtained is reduced to so low a figure as to be usually negligible.



"Oxygen absorbed" Test.—In the determination of "oxygen absorbed" from permanganate, the permanganate used has invariably been a solution of "strong," *i.e.*, $\frac{N}{8}$ permanganate (3·94 grm. Kmn O_4 per litre).

Incubator Test.—The incubation results are given as (*a*) Incubator test (Scudder) and (*b*) Incubator test (by smell).

In the case of (*b*), the sample was said to "fail" if it had a putrid smell after incubation. With regard to (*a*), it is not strictly correct to refer to this as Mr. Scudder's incubator test. He uses "weak" permanganate (0·394 grm. per litre) and allows it to act for three minutes, while we have used "strong" permanganate and have titrated "at once", *i.e.*, after the lapse of about half a minute. In summarizing the results obtained on incubation, the test "by smell" is referred to.

Determination of Absorption of Dissolved Oxygen.—The determination of dissolved oxygen absorption by effluents, etc., has been made in nearly every case by Winkler's manganese method, as modified by Rideal and Stewart, though in some instances the copper chloride method of Ramsay and Miss Homfray has been used.

The earliest part of the chemical work of this Appendix was carried out by Miss Harriette Chick, D.Sc. The greater part of it was, however, done by Mr. R. B. Floris, F.I.C., now Chief Chemical Assistant under Dr. Houston, Director of Water Examinations, Metropolitan Water Board; Mr. R. F. Finlow, B.Sc., now one of the Agricultural Chemists to the Indian Government; Mr. Eric H. Richards, B.Sc., who has for nearly four years past been in charge of the Commission's Experimental Station at Dorking; and Mr. A. C. Carter, F.I.C.; while Mr. A. F. Girvan, B.Sc. and Mr. W. G. Winterson, B.Sc., have also given material assistance in the later stages. The work has often been very arduous, but it has been carried out for the Commission by Miss Chick and the various gentlemen named with the utmost care and thoroughness, so that it is a duty as well as a pleasure to draw attention to it. At the same time I should like to express my own hearty thanks to them for the constant and unwearied help which they have given to me.

George McGowan.

Note by Dr. Houston.

Most of the bacteriological analyses in connection with this enquiry were carried out by Miss Hartley, and the work was most efficiently and carefully done. I have also, however, to acknowledge the able assistance rendered during the earlier stages of the investigation by Miss Chick and by Miss Power.

A. C. Houston.

ACCRINGTON AND CHURCH OUTFALL SEWAGE WORKS.

1. Situation of works - - - - - -	Coppy Clough, about 1 mile from the centre of the districts sewered.
2. Method of treatment - - - - -	Open septic tank followed by continuous filtration through percolating filters of coarse material.
3. Population draining to works during observations	46,300 (estimated average).
4. Water supply in gallons per head and whence obtained - - - - - - -	21.—Local gathering grounds—a fairly soft water.
5. Number of W.C's - - - - - -	10,000.
6. Sewerage system - - - - - -	Combined.
7. Average dry weather flow in gallons per 24 hours	1,180,000.
8. Gallons of sewage per head per day - - -	25·4.
9. Character of the sewage - - - - -	A strong domestic sewage.*
10. Period of observations - - - - -	July, 1900 to Dec., 1904.
11. Age of filters - - - - - - -	From three months to two years.
12. Amount of storm water treated on filters during observations	About twice the dry weather flow.
13. Total capacity of tanks in gallons - - -	2,077,180.
14. Total area of filters in yards super. - - -	4,522.
15. Total cubic content of filters in yards cube -	12,934.
16. Nature of filtering medium - - - -	2 filters, clinker, 12 filters, coke.
17. Gallons of tank liquor treated per yard super. per 24 hours (all filters included) - - - -	400 to 450.
18. Gallons of tank liquor treated per yard cube per 24 hours - - - - - - -	133 to 150.
19. The final effluent is discharged into - - -	The river Hyndburn, a small stream polluted by discharges from print and dye-works which flows into the rivers Calder and Ribble.

* The majority of the population is served by water closets constructed on what is called the "waste-water system," in which the closets are flushed with slop water and in wet weather also by water from the back roofs of the houses. But a considerable portion of the population is still served by the pail system, there being something like 2,000 pails; as the contents of these are tipped into a tank at the depôt which is flushed into the sewers twice a day, they may be looked upon as having much the same effect on the sewage as water-closets.

FLOW OF SEWAGE.

As a result of the combined system of sewers, the volume of sewage carried to the works is much increased during wet weather. There are thirteen overflows on the system, however, which come into operation at six times the dry weather flow, and one of these is situated close to the works on the main sewer. More than six times the dry weather flow, therefore, is seldom brought to the works.

Up to the year 1901, *i.e.*, during a part of our observations, the whole of this increased volume up to six dilutions was passed through the septic tanks, but not more than twice the dry weather flow was filtered, the rest of the septic liquor being turned direct to the river. Since 1901, however, the authorities have, at the suggestion of the Ribble Committee, diverted everything above twice the dry weather flow by means of the storm overflow situated on the main sewer. From this time, therefore, not more than about twice the dry weather flow has been passed either through the septic tanks or on to the filters.

As the flow of sewage at Accrington has been carefully gauged by Mr. W. J. Newton, the Borough Surveyor, we have thought it unnecessary to make any gaugings ourselves.

The dry weather flow is 1,180,000 gallons per day. It is of a rather uneven character, and varies, as a rule, from a maximum rate of something like 1,500,000 gallons per day, which occurs at about 6 p.m., to a minimum rate of about 700,000 gallons per day, which continues during the night and the early hours of the morning. The highest day's flow of about 1,240,000 gallons occurs on the Monday of the week, and the lowest, about 800,000 gallons, on the Sunday. In very wet weather, owing chiefly to the combined system of sewers and the hilly nature of the district, the fluctuations in the flow are both large and rapid.

Subsoil Water.—Mr. Newton estimates the amount of subsoil water gaining access to the sewers to be about one-sixth of the total daily dry weather flow.

Crude Sewage.—Three sets of hourly samples of crude sewage, one chance sample, and a sample of storm overflow discharge were examined chemically.

Of the *hourly samples*, No. 2,894, drawn at the end of August, 1900, in dry weather, represented an average of 72 hours (Monday to Wednesday), in equal fractions every hour.* No. 2,898, drawn in the middle of October, 1900, was an average of 24 hours (Monday to Tuesday), in hourly fractions according to the rate of flow. No. 2,903, drawn at the beginning of November, 1900, during rather wet weather, was an average of the whole seven days of one week, in hourly fractions taken roughly according to rate of flow. Although its composition no doubt altered to some extent in the course of the week, the figures of analysis are given here, mainly with a view to the suspended solids.

The chance sample of sewage, marked "C," was drawn on Wednesday, February 19th, 1902, at 12.10 noon, the sewage being at the time somewhat diluted with melted snow.

No. 3,424 was a sample of storm overflow discharge, drawn in *dry* weather on Tuesday, March 15th, 1904, at 3.45 p.m., with the storm overflow just working.

The figures of analysis of the above samples had best be given separately.

Parts per 100,000.	Hourly Samples.			Chance Sample.	Storm Overflow Discharge.
	No. 2,894.	No. 2,898.	No. 2,903.	"C."	3,424.
Ammoniacal Nitrogen	5·92	4·44	2·30	6·59	3·74
Albuminoid Nitrogen	0·74	0·62	0·54	1·90	1·40
Total Organic Nitrogen	3·46	2·15	1·92	4·13	4·60
Total Nitrogen	9·38	6·59	4·22	10·72	8·34
"Oxygen absorbed" *in 3 minutes* at 27° C. (80° F.)	4·50	1·55	2·11	6·59	3·97
"Oxygen absorbed" *in 4 hours* at 27° C. (80° F.)	17·08	9·93	8·75	27·55	34·03
Chlorine				16·26	8·60
Solids in Suspension	56·60	29·90	30·30		49·40
Solids by Centrifuge (vols.)				338·0	283·0
Ratio of Solids in Suspension to Centrifuge Solids					1 : 5·7
Total Iron (expressed as Metallic Iron, Fe)	0·91	0·86			

* The fractions from 2 a.m. to 5 a.m. each day were omitted because of the very small flow at that time.

The foregoing figures show that the Accrington dry-weather summer sewage is distinctly strong in every respect, and with a large quantity of suspended solids; in wet weather it falls to about average strength or less, though the solids apparently never reach a very low figure. The chance sample, "C," drawn at mid-day in the month of February after a week's frost, but with some water from melted snow getting into the sewers, was an exceedingly strong sample. The sewage, therefore, which the septic tanks and filters at Accrington have to treat is generally over average strength.

It will be noted that this sewage contains about one part of iron per 100,000.

The sample of storm overflow discharge examined, No. 3,424, was, as already mentioned, drawn in dry weather. It was a particularly strong sewage.

Bacteriological Notes.—Only a few samples of crude sewage were examined and the results are given in a later portion of this report.

The Screens.—On its way to the septic tanks the sewage passes through a half-inch screen, which is raked by means of a hand wheel about once an hour throughout the day. The screenings are mixed with dried sludge and sent away to the land in sludge boats.

THE SEPTIC TANKS.

Number - - 6.

DIMENSIONS AND PARTICULARS.

Number.	Depth of Tank.	Dimensions.	Area in square yards.	Area in square feet.	Capacity in gallons.
1	8ft. 6in.	101ft. 9in. × 59ft. 8in.	674·5	6,070·5	322,495
2	8ft. 6in.	101ft. 9in. × 59ft. 8in.	674·5	6,070·5	322,495
3	9ft. 0in.	101ft. 8in × 58ft. 2in.	657	5,913	332,610
4	9ft. 0in.	101ft. 8in. × 58ft. 2in.	657	5,913	332,610
5	9ft. 0in.	101ft. 0in. × 67ft. 6in.	757·5	6,817·5	383,485
6	9ft. 0in.	101ft. 0in. × 67ft. 6in.	757·5	6,817·5	383,485
			4,178	3,7602	2,077,180

Total capacity - - 2,077,180 gallons.

Construction.—Brick and cement with concrete bottoms. Each tank is fitted with sludge valves and floating arms, for the purpose of cleaning.

Flow Through.—With the dry weather flow of 1,180,000 gallons per day, the flow through the six tanks generally in use during our observations would be once in 42 hours, at the rate of 1·45 inches per minute.

Working.—During the observations six tanks have as a rule been at work, used in two series of three tanks each. Originally they were worked as one series of six, but it was found that a better tank liquor—more particularly as regards suspended matter—was obtained by using the tanks in two series of three, the reason for this being that the rate of flow through any one tank was thus reduced by one half.

Towards the end of the observations, however, a third method was adopted. In this the sewage passes through one preliminary tank and is then divided, half of it flowing through the two subsequent tanks on the one side and half through the two tanks on the other. The preliminary tanks are therefore used alternately for the ordinary flow. The object of this plan is that one preliminary tank may be kept empty to deal with the first rush of storm-water during wet weather.

Sludging.—The length of time between two sludgings of the septic tanks at Accrington depends largely upon the rate at which the sludge from the earlier cleaning dries in the lagoons. The history of the tank sludging cannot, therefore, be considered as a true criterion of the method which the authorities would adopt if more space was available for lagoons. It may be said, however, that the tendency now is to sludge the tanks, and especially the two preliminary tanks, more frequently than before.

Since the commencement of the septic process in February, 1898, up to the end of our observations, the cleanings have been as follows :—

February, 1898 - - - - - - -	Tanks first used.
July, 1898 - - - - - - -	All tanks sludged.
July, 1899 - - - - - - -	All tanks sludged.
April, 1900 - - - - - - -	Tanks Nos. 1, 5, and 6 sludged.
November, 1900 - - - - - -	Tank No. 2 sludged.
July, 1901 - - - - - - -	All tanks sludged.
July, 1902 - - - - - - -	All tanks sludged.
November, 1902 - - - - - -	Tanks Nos. 1 and 2 sludged.
August, 1903 - - - - - -	All tanks sludged.
June, 1904 - - - - - - -	All tanks sludged.
October, 1904 - - - - - -	All tanks sludged.

After drawing off the supernatant liquor the sludge is removed, by allowing it to gravitate to the sludge lagoons, where it dries naturally. When dry enough to be spadeable, it is sent up the steep side of the quarry by means of a truck-way and deposited in the barges on the canal, to be taken to the more agricultural districts in West Lancashire. The barge-owners pay on the average about £2 10s. per boat-load of 45 tons. The boats are loaded by the Board, the average cost of filling a boat from the works being about 25s.

The drying process is naturally a slow one, and until the sludge becomes fairly dry a considerable smell is often apparent round the lagoons. In dry weather the sludge may become spadeable in from two to three months, while in wet weather it may require about six months.

Careful calculations have been made by Mr. Newton in order to determine the difference between the present sludge production and that when precipitation was in vogue. They show that at Accrington the septic process, although giving a tank liquor which contains a larger quantity of suspended matter than the precipitation process gave, effects a reduction of approximately 75 per cent. in the sludge to be dealt with. The actual quantity of septic sludge produced, per annum, only amounts to an average of about 3,000 tons; it contains, as a rule, about 90 per cent. of water.

The evidence as to the degree of digestion of sludge in the septic tanks at Accrington appears to show that this is only small, and that the three main reasons for the difference between the sludge produced from the present septic tanks and the former precipitation tanks are :—

(1) That the chemicals brought down a considerable quantity of solid matter which is not precipitated from solution by the septic treatment.

(2) That the sludge obtained from the septic tanks is more concentrated than that from the precipitation tanks ; and

(3) That a great deal more suspended matter goes away in the septic tank liquor than was the case in the precipitation liquor.

Septic Tank Liquor.—Seven sets of hourly samples and four chance samples were examined chemically. Of the hourly sets, which were all taken in equal fractions per hour, No. 2,895, drawn at the end of August, 1900, in dry weather, represented 72 hours' flow* ; No. 2,899, drawn in the middle of October, 1900, 48 hours ; and No. 2,904, drawn in the early part of November, 1900, one week's flow. Speaking roughly, at the time those samples were taken, three of the six tanks had run for over a year without being cleaned, and the other three had run for four to six months. The remaining four sets were drawn in May, June, July and September, 1901, mostly or altogether in warm, dry weather, each of them over a period of 24 hours. Since all the tanks were sludged in July, 1901, the two last sets of samples (July and September) were taken shortly after this cleaning. The

* The fractions from 2 a.m. to 5 a.m. each day were omitted.

above sets, taken altogether, probably give rather higher figures than the true average of the composition of the septic tank liquor at Accrington for the year ending September, 1901, seeing that five of the seven sets were drawn in the warmer months of the year.

The following results were obtained :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(2·34 to 6·75)	5·03	(7)
Albuminoid Nitrogen	(0·29 to 0·81)	0·34	(7)
Total Organic Nitrogen	(1·46 to 2·42)	1·81	(7)
Total Nitrogen	(4·00 to 8·38)	6·84	(7)
"Oxygen absorbed" *in* 3 *minutes* at 27° C. (80° F.)	(1·51 to 3·20)	2·17	(7)
,, ,, *in* 4 *hours* ,, ,,	(6·64 to 11·04)	8·67	(7)
Solids in Suspension	(14·30 to 22·10)	19·40	(7)
Solids by Centrifuge (vols.)	(132·0 to 240·0)	173·0	(4)
Ratio of Solids in Suspension to Centrifuge Solids	(1 : 7·4 to 1 : 12·2)	1 : 9·3	(4)
Iron (expressed as Metallic Iron, Fe.)	(0·54 and 0·80)		(2)

Apart from the lower figure of 14·3 obtained for suspended solids in the sample of July, 1901, which was taken shortly after all the tanks had been sludged, the five sets of samples taken in the warmer months of the year were stronger than the two drawn in October and November, especially as regarded ammonia and nitrogenous matter generally. The tank liquor thus varies considerably in strength at different seasons and under different conditions of weather. The remarkably high and very constant figures given for suspended solids (average 19·4 parts) are especially noteworthy. The settlement of solids by the septic tanks was thus very poor throughout the year in question.

The liquid passing on to the filters at Accrington is thus strong organically, and at the time when the above observations were made it contained an exceptionally large quantity of black flocculent matter in suspension.

Comparing the first three sets of septic tank liquor, Nos. 2,895, 2,899 and 2,904, drawn in August, October and November, with the corresponding three sets of sewage, Nos. 2,894, 2,898 and 2,903, we find the following differences in figures :—

	Reduction.
Total Nitrogen	15 per cent.
Ammoniacal Nitrogen	+ 0 ,,
Albuminoid Nitrogen	48 ,,
Total Organic Nitrogen	18 ,,
"Oxygen absorbed" *in* 3 *minutes*	36 ,,
,, ,, *in* 4 *hours*	33 ,,
Solids in suspension	47 ,,
Iron (two samples)	34 ,,

The suspended solids were thus brought down by the septic tank treatment to about half what they were in the sewage, while the ammoniacal nitrogen remained the same, and the other oxidisable matter, as measured by the "oxygen absorbed" test, was reduced by about one-third.

Chance Samples.—The four chance samples of septic tank liquor examined chemically were drawn in the months of February and November, 1902, and January and April, 1903, being thus all taken in the cooler months of the year. No. "D" was drawn during

a thaw after a week's frost, Nos. 3,056a and 520 in dry weather, and No. 3,086a (a very dilute sample) in dry weather following a period of wet. These gave the following figures on analysis :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(5·59 and 5·23)	—	(2)
Albuminoid Nitrogen	(0·83 and 0·76)	—	(2)
Total Organic Nitrogen	(2·01)	—	(1)
Total Nitrogen	(3·42 to 7·60)	5·96	(3)
"Oxygen absorbed" *at once*, at 27° C. (80° F.)	(1·16 to 6·13)	3·24	(4)
,, ,, *in 4 hours* ,, ,,	(4·52 to 12·45)	10·12	(4)
Chlorine	(12·68 and 8·48)		(2)
Solids by Centrifuge (vols.)	(33·0 to 62·0)	51·0	(4)

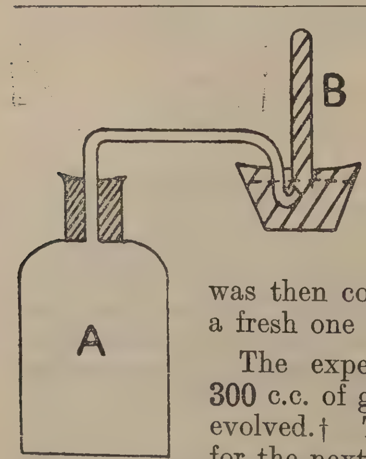
It will be seen that while, on the average—apart from the question of suspended solids—the above chance samples did not differ materially from the average of the hourly samples, the individual variations were greater ; but the general character of the liquid was the same. Judged from the centrifuge figures, however, the suspended solids in those chance samples were only about one-third of what they were in the hourly, *i.e.*, approximately, 6 parts per 100,000 ; but in regard to this it has to be borne in mind that all the tanks were sludged in July, 1901, and again in July, 1902.

Bacteriological Notes.—Only a few samples of septic liquor were examined. The results are given in a later part of this report.

Experiment with Septic Tank Sludge, to see how far the sludge had been digested in the Septic Tank.—On November 21st and 22nd, 1900, an average sample of sludge was drawn from No. 2 tank, after the latter had been in use for four months and was in process of being cleaned out. At this time the tanks at Accrington were all used in one series of six, No. 2 tank forming the first of the series.

An examination of the sludge was begun on December 18th, 1900 ; it had then a very offensive smell and was continuing to give off gas. It contained :—

Calculated on	Wet Sludge ;	Dry Sludge.
Water	83·0 per cent.	—
Matter volatile on ignition	8·8 ,,	51·9 per cent.
Residue after ignition	8·2 ,,	48·1 ,,
	100·0 ,,	100·0 ,,



On December 19th, 14·6 grms. of the wet sludge (equivalent to 2·484 grms. of dry matter) were transferred to a bottle of 826 c.c. capacity, into the rubber stopper of which a gas delivery tube was fitted. The bottle and delivery tube were then completely filled with distilled water (which contained approximately 6 c.c. of oxygen and probably about 11 c.c. of nitrogen per litre*). The gas evolved from the mixture of sludge and water in bottle A, at laboratory temperature, was then collected over mercury in tube B, this tube being replaced by a fresh one whenever it became nearly full.

The experiment is not yet completed (January, 1906), but at least 300 c.c. of gas, consisting mainly of methane, have up to the present been evolved.† The evolution was very rapid for two months and fairly rapid for the next five months, *i.e.*, up to August, 1901. Since that time gas has continued to be given off slowly during the warmer months of each year.

* The nitrogen was not actually determined in this sample of water.

† The sulphuretted hydrogen given off is not included here, as it was, of course, taken up by the mercury present.

The experiment not being yet at an end, nothing further need be said at present excepting that (1) this sludge had been withdrawn from the septic tank long before it had been fully decomposed, and (2) the decomposition of such sludge *under the above conditions of experiment* is a very slow process.* In considering the disposal of sludge by digestion in septic tanks, as compared with other methods, this point has to be borne in mind.

FILTERS.

Number - - 14.

DIMENSIONS AND PARTICULARS.

No. of Filter.	Diameter of Filter.		Superficial Area.	Depth of Filter.		Cubic Content.	Remarks.
	Ft.	Ins.	Square Yards.	Ft.	Ins.	Cube Yards.	
1	62	0	364	9	3	1122·30	2-inch Coke, Automatic Distributor.
2	62	0	364	8	6	1031·30	,, ,, ,, ,,
3	62	0	364	9	3	1122·30	,, ,, ,, ,,
4	62	0	364	7	0	849·30	,, ,, ,, ,,
5	49	9	220½	8	0	588·20	2-inch Clinker, Steam Distributor.
5A	49	9	220½	8	0	588·20	,, ,, ,, ,,
6	49	9	220½	9	0	661·80	2-inch Coke ,, ,,
6A	49	9	220½	9	0	661·80	,, ,, ,, ,,
7	62	0	364	8	6	1031·30	,, ,, ,, ,,
8	62	0	364	9	0	1092·00	,, ,, ,, ,,
9	62	0	364	8	6	1031·30	,, ,, ,, ,,
10	62	0	364	8	6	1031·30	,, ,, ,, ,,
11	62	0	364	9	0	1092·00	,, ,, ,, ,,
12	62	0	364	8	6	1031·30	,, ,, ,, ,,

Total superficial area - - - - 4,522 square yards.
Total cubic content - - - - 12,934·4 cube yards.
Material, 12 beds - - - - - Coke ranging from 2 inches to 4 inches in diameter.
2 beds - - - - - Clinker ranging from 2 inches to 4 inches in diameter.

Construction.—The construction of the filters is simple, the material being built up on a false bottom consisting of large semicircular perforated pipes, which rest on a concrete floor, and kept in position by a wall of pigeon-hole brickwork constructed in the form of an octagon. This is carried up to a height of some 7 or 8 feet above the concrete floor, the material from that point to the surface of the bed being given a slight batter towards the centre.

Distribution.—Three kinds of distributors are in use:—

(1) Ten filters.

Whittaker sprinklers driven by the impulse of the liquid issuing from the jets in the sprinkler arms, the liquid being pumped into the arms by means of a pulsometer.

(2) Three filters.

Candy-Whittaker sprinklers which work automatically by means of the head of liquid in the septic tank.

(3) One filter.

An automatic stationary distributor in which the periodical discharge from a small reservoir is distributed by means of a large number of perforated iron pipes, laid on the top of the material. The discharge takes place about once every ten minutes, and continues for two or three minutes.

* It must not be forgotten here that the products of the bacterial action, other than the gaseous ones, remained in the liquid, and that no fresh pabulum was introduced. Under the ordinary conditions of tank working this would not be the case, and the decomposition might therefore be more rapid.

The distribution in all three cases is good. The effluent from the sprinkler-fed filters however, is as a rule rather better and more highly nitrated than the effluent from the filter fed by means of the stationary distributor. This is clearly shown by Mr. Boothman's monthly average analyses (six analyses a month) from November, 1902, to April, 1904, which we have been allowed to quote :—

Filters treating equal quantities of Septic Tank Liquor per cube yard per 24 hours.	Parts per 100,000.	
	Oxygen absorbed from Permanganate in 4 hours at 80° F., by Effluents after paper filtration.	Nitrogen as Nitrate and Nitrite.
Average analysis of effluent from No. 3 (9 ft. 3 in. deep) bed, which is fed by means of an automatic sprinkler - - - - - -	0·72 *	2·17
Average analysis of effluent from No. 4 (7ft. deep) bed, which is fed in intermittent flushes from a stationary distributor - - -	0·84 *	1·75

The difference may probably be assigned to three causes :—

(1) That the material in No. 4 Filter is 2 feet 3 inches less in depth than in Filter No. 3;

(2) That the distribution given from the sprinklers is rather better than that given by the stationary distributor; and

(3) That, as considerable unevenness in the flow of effluent from the filter fed by the stationary distributor is noticeable, the conditions of oxidation in this bed cannot be so uniform; probably, too, the passage of a portion of the tank liquor through it is more rapid than in the case of the sprinkler-fed filters.

With regard to the comparison of the effluent from the filters fed by the pulsometer-driven sprinklers and the automatic sprinklers, it may be said that there appears from our observations to be little difference. This statement is corroborated by a large number of comparative figures given in Table I. of Mr. Newton's report for the year ending March 31st, 1904. The following are the average figures for "oxygen absorbed" from permanganate and oxidised nitrogen given in that report.

Parts per 100,000.	Oxygen absorbed from Permanganate in 4 hours at 80° F.	Nitrogen present as Nitrates and Nitrites.
Final effluent from filters fed by pulsometer-driven sprinklers -	1·40	2·07
Final effluent from filters fed by automatic sprinklers - - -	1·41	2·13

Although, therefore, the temperature of the tank liquor put upon the filters fed by the pulsometer-driven sprinklers was raised at this time about 6° or 7° Fahrenheit, there was very little difference in quality between the effluent and that resulting from the filters fed by the automatic sprinklers, which treated unwarmed tank liquor.

Working.—The majority of the filters work continuously without rest, but in dry weather the whole of the sewage can be treated by twelve of the fourteen filters, which allows of two filters being given a short rest at such times.

Age of Filters.—All the filters at Accrington were constructed between August, 1898, and May, 1902, as follows :—

Nos. 5, 5a, 6 and 6a - - - - - August and November, 1898.
Nos. 7, 8 and 9 - - - - - - August, 1899.
Nos. 10, 11 and 12 - - - - - April, 1900.
Nos. 1, 2 and 4 - - - - - - April, 1901.
No. 3 - - - - - - May, 1902.

* The solution of potassic permanganate used for this test was $\frac{N}{80}$ in strength; the above figures are therefore lower than would have been obtained with the $\frac{N}{8}$ permanganate which we employ—probably about two-thirds as great.

At the end of our observations, therefore (December, 1904), they varied in age from rather more than six years to rather less than two years.

When the observations commenced, in 1900, the ten filters then at work were in good condition and free from any serious clogging. Some local pooling upon the surface has been noticed from time to time, due apparently to the workmen walking upon the beds, in order to clean the arms of the sprinklers; but at any time when this has occurred, it has easily been remedied by careful forking. At the end of the observations, in December, 1904, all the filters appeared to be in much the same condition as at the commencement.

Unsettled Effluents, Hourly Samples.—Four sets of hourly samples were examined chemically, Nos. 2,923a, 2,925, 2,927a and 2,929a, each sample extending over twenty-four hours. Like the similar sets of septic tank liquor, they were drawn in the months of May, June, July and September, 1901, three of them, at all events, in warm, dry weather.

They gave the following figures on analysis :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - - - -	(0·87 to 1·37)	1·07	(4)
Albuminoid Nitrogen - - - - - - -	(0·13 to 0·34)	0·27	(4)
Total Organic Nitrogen - - - - - -	(0·90 to 3·34)	2·11	(4)
Oxidized Nitrogen- - - - - - -	(1·45 to 2·75)	2·24	(4)
Total Nitrogen - - - - - - - -	(4·52 to 6·51)	5·42	(4)
" Oxygen absorbed " *in* 3 *minutes* at 27° C (80° F.) -	(1·04 to 1·76)	1·42	(4)
,, ,, *in* 4 *hours* ,, ,, -	(3·60 to 6·64)	5·08	(4)
Incubator Test (Scudder) * - - - - - -		4 passed†	(4)
Incubator Test (by Smell) - - - - - -		4 passed	(4)
Solids in Suspension - - - - - - -	(11·60 to 30·50)	20·00	(4)
Solids by Centrifuge (vols.) - - - - -	(140·0 to 290·0)	214·0	(4)
Ratio of Solids in Suspension to Centrifuge Solids	(1 : 9·2 to 1 : 12·1)	1 : 11·2	(4)

The above effluents were very turbid and brown with suspended matter, which however settled pretty quickly, leaving the liquid fairly clear and colourless. They all had a clean smell both when drawn and when analysed, were well nitrated, and readily withstood incubation. As regards the liquid portion, therefore, they were effluents of good class (cf. below). The most striking point about them was the unusually large quantity of flocculent suspended solids that they contained—an average of 20 parts, and it is very noteworthy here that the May and June samples had respectively 30·5 and 25·7 parts, owing to the spring "flush out" from the filters. It is hardly necessary, therefore, to say that these effluents required to have their suspended matter removed before being discharged into a stream.

An examination of some *Filter effluent sludge*, collected at the same time as the unsettled effluent, No. 3,456, was made on May 5th, 1904. The sample was collected on May 4th by siphoning off the liquid from a pailful of effluent, after allowing it to stand quiescent for three hours. Most of the suspended matter in the Accrington effluent settles in about one hour.

The following figures were obtained :—

	Parts per 100,000.	
Solids in suspension - - - - - - - - - -	2758·0	{ 1,471 Volatile. 1,287 Non-volatile.
Total Nitrogen - - - - - - - - - {(a) 95·25 (b) 95·82}	95·54	
" Oxygen absorbed " *at once* at 27° C. (80° F.) - - - -	137·6	
,, ,, *in* 4 *hours* ,, ,, - - - - -	773·2	
Dissolved Oxygen taken up from water at 18° C. in 48 hours ‡ -	32·1	
,, ,, ,, ,, ,, ,, 96 ,, -	41·5	

* The nitrous nitrogen was not determined after incubation, and the assumption is made that it was not greater then than before.

† One of them practically passed.

‡ A 24 hours' estimation was not in accordance with those for 48 and 96 hours, so the figure is not given.

On the day of analysis this effluent sludge, which was watery, with finely divided solids, had a clean, strong earthy smell. Although, therefore, it was not rapidly putrescent, the above figures of analysis leave no doubt as to its polluting nature.

Compared with the four corresponding samples of septic tank liquor, Nos. 2,922, 2,924, 2,926 and 2,928, the foregoing hourly samples of unsettled effluents show the following differences in figures. Apart from the figures for suspended solids, which, of course, affect those for albuminoid, total organic, and total nitrogen and for "oxygen absorbed" from permanganate, it is seen that four-fifths of the ammoniacal nitrogen of the septic tank liquor has been oxidized or given off as gas in the passage of the liquid through the filters :—

Calculated on—	Reduction.
Total Nitrogen	29 per cent. reduction.
Ammoniacal Nitrogen	81 „ „
Albuminoid Nitrogen	53 „ „
Total Organic Nitrogen	4 „ increase.
"Oxygen absorbed" *in* 3 *minutes* at 27° C. (80° F.)	48 „ reduction.
„ „ *in* 4 *hours*	45 „ „
Solids in suspension	8 „ increase.
Solids by centrifuge (vols.)	24 „ „

Before offering any further criticism of the above effluents, reference may be made to the following various analyses of duplicate samples of them, under different conditions.

Paper-filtered Effluents.—Nos. 2,923a, 2925, 2,927a and 2,929a. All four effluents were also examined after filtration through paper. The figures obtained for ammoniacal and for oxidized nitrogen were, of course, practically the same as those from the original samples, but there was a material difference in other respects, thus :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(0·86 to 1·36)	1·04	(4)
Albuminoid Nitrogen	(0·08 to 0·13)	0·11	(4)
Total Organic Nitrogen	(0·74 to 2·43)	1·63	(4)
Oxidized Nitrogen	(1·45 to 2·71)	2·24	(4)
Total Nitrogen	(4·36 to 5·67)	4·88	(4)
"Oxygen absorbed" *in* 3 *minutes* at 27° C.	(0·32 to 0·64)	0·58	(4)
„ „ *in* 4 *hours* „	(1·52 to 2·24)	1·82	(4)

All these filtered effluents, of course, withstood incubation (not noted in case of No. 2,925). The filtered liquid of No. 2,929a was noted as being somewhat turbid and brown, and that of No. 2,923a deposited a white precipitate upon incubation.

If we compare these paper-filtered with the original unsettled effluents, and also with the four corresponding septic tank liquors, we find the following reduction in figures :—

Calculated on—	Compared with—	
	Original Effluents.	Septic Tank Liquors.
Total Nitrogen	10 per cent. reduction	36 per cent.
Ammoniacal Nitrogen	—	82 „
Albuminoid Nitrogen	59 per cent. reduction	81 „
Total Organic Nitrogen	23 „ „	19 „
"Oxygen absorbed" *in* 3 *minutes*	59 „ „	79 „
„ „ *in* 4 *hours*	64 „ „	80 „

The elimination of the suspended solids by filter paper thus reduced the impurities of the original effluents, as measured by the albuminoid nitrogen and "oxygen absorbed" tests, by about 60 per cent. of the total.

The reduction in the paper-filtered effluents, as compared with the septic tank liquors, works out to about 80 per cent., on the above tests.

Three duplicates of the above *Unsettled Effluents*, Nos. 2923a, 2927a and 2929a, were also analysed after being incubated for seven days at 27° C. (80° F.), and the average figures of their analyses may be contrasted with the corresponding averages of the originals, thus :—

	Incubated Samples.	Original Samples.
Ammoniacal Nitrogen	1·02	0·97
Albuminoid Nitrogen	0·28	0·25
Total Organic Nitrogen	2·23	2·22
Oxidized Nitrogen	1·14	2·30
Total Nitrogen	4·48	5·32
"Oxygen absorbed" *in* 3 *minutes* at 27° C.	1·41	1·36
" " *in* 4 *hours*	4·80	4·80
Solids in suspension	Not estimated.	18·10

The main result of the incubation was to reduce the nitric nitrogen by about 1·2 parts. Considering the large quantity of suspended matter present, viz., 18 parts (53 per cent. of which was volatile on ignition), this was only to be expected; indeed, the fact of the reduction of nitrate not having gone further shows that the suspended or other matter, while putrescible, only took up oxygen (from the nitrate) very slowly—a sign of good previous oxidation by the filters.

The remaining duplicate hourly sample of unsettled effluent, No. 2925, instead of being incubated, was kept in an open bottle at laboratory temperature for five days, and then analysed with the following result; the figures for the original effluent are again given alongside :—

	No. 2925.	
	Kept in open bottle for 5 days.	Original Sample.
Ammoniacal Nitrogen	1·22	1·37
Albuminoid Nitrogen	0·39	0·34
Total Organic Nitrogen	2·59	3·11
Oxidized Nitrogen	2·19	2·04
Total Nitrogen	6·00	6·51
"Oxygen absorbed" *in* 3 *minutes* at 27° C. (80° F.)	1·44	1·60
" " *in* 4 *hours* " "	5·92	5·92
Solids in Suspension	Not estimated.	25·70

Making some allowance for differences in sampling an effluent containing so much suspended matter, and for errors of analysis, it is evident that this unsettled effluent underwent practically no change during the five days that it was exposed to the air—again a satisfactory result.

Unsettled Effluents—Chance Samples.—Eighteen chance samples of unsettled effluent were examined chemically, some in duplicate (cf. below). Six of them, however, were drawn within a period of one week, in May, 1901, for the purpose of gaining an idea of the amounts of suspended solids washed out of the filters during the spring "outflush," and these will therefore be discussed separately. The other twelve samples, Nos. 2911, 2912, 2913, 2914, 2915, "A," "B," "E," 3086b, 521, 3422 and 3456, were drawn between February, 1901, and May, 1904, all of them in the months January to May, *i.e.*, in the cooler seasons of the year. No. "E" was drawn with the object of observing the "outflush" of solids, on May 10th, 1902, but it did not contain an excessive amount of these, and is therefore included with the other samples just mentioned. No. 3455, drawn on May 4th, 1904, which contained 14·7 parts of solids, is also included.

The following results were obtained on analysis :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(0·49 to 2·50)	1·33	(8)
Albuminoid Nitrogen	(0·09 to 0·33)	0·25	(8)
Total Organic Nitrogen	(0·66 to 1·74)	0·93	(7)
Oxidized Nitrogen	(0·27 to 3·16)	1·60	(11)
Total Nitrogen	(1·85 to 4·86)	3·73	(7)
"Oxygen absorbed" *at once** at 27° C. (80° F.)	(0·15 to 1·55)	0·83	(11)
" " *in 4 hours*	(1·33 to 5·24)	3·02	(11)
†Incubator test (Scudder)		9 passed 1 nearly passed	(10)
†Incubator test (by smell)		11 passed	(11)
Smell when drawn		7 good	(7)
Smell when analysed		7 good	(7)
Chlorine	(5·56 to 11·80)	8·84	(5)
Solids in suspension	(1·70 to 14·70)	8·90	(8)
Solids by centrifuge (vols.)	(37·5 to 194·0)	107·0	(10)
Ratio of solids in suspension to centrifuge solids	(1 : 8·6 to 1 : 22·1)	1 : 11·8	(7)
Dissolved oxygen taken up *in 24 hours*	(0·81 to 1·21 ap.)‡	0·96 ap.	(4)
	c.c. per litre.		
Oxygen in solution when analysed	(0·0 to 5·0 ap.)	2·1 ap.	(7)

In appearance these effluents might be described as opalescent, and turbid with flocculent suspended matter, but they yielded for the most part a clear liquid of brownish tinge when filtered through paper. Seven were noted as having a clean smell when drawn (tarry, in one case) and seven a clean smell when analysed, and the same no doubt applied to the whole of the twelve effluents. All of them withstood the incubator test.§ As regards nitration, the first five effluents, drawn between February and April, 1901, showed an average of only 0·47 part of oxidized nitrogen, *i.e.*, they were relatively poorly nitrated; while the remaining six, drawn in the spring months of 1902, 1903 and 1904, had an average (and almost a constant quantity) of 2·54 parts, being well nitrated. The main reason for this difference, no doubt, was that latterly more filters were in use.

The suspended solids in the above unsettled effluents varied between 1·7 and 14·7 and averaged 8·9; the effluents therefore required settlement. Some of the solids were found to be putrescent, when tested, and this no doubt applied in every case. The figures for "oxygen absorbed" from permanganate were rather high, but this was, of course, largely due to the suspended solids present.

Taking the effluents all together, they may be described as effluents of fair quality, but requiring settlement of the (putrescible) organic matter which they contained in suspension; as has been already stated, they do receive settlement at the works before being finally discharged.

Compared with the three sets of hourly samples of sewage and the seven sets of hourly samples of septic tank liquor the above twelve chance samples of unsettled effluent show the following reduction in figures (the numbers in brackets indicate the estimations in each case) :—

Calculated on—	Compared with— Sewage.	Compared with— Septic Tank Liquor.
	Reduction.	Reduction.
Total Nitrogen	45 per cent. (7)	45 per cent. (7)
Ammoniacal Nitrogen	68 " (8)	74 " (8)
Albuminoid Nitrogen	60 " (8)	26 " (8)
Total Organic Nitrogen	63 " (7)	49 " (7)
"Oxygen absorbed" *in 4 hours*	75 " (11)	65 " (11)
Solids in suspension	77 " (8)	54 " (8)

* The absorption of the first five samples was *in 3 minutes.*
† Assumed in one case. Nitrite not determined after incubation in the first five samples.
‡ Ap. = approximately.
§ This was not noted in the case of No. 2,912, but it may be inferred from the rest of the analysis.

Spring Outflush of Solids from Filters.—The six samples, Nos. 2916, 2917, 2918, 2919, 2920 and 2921, which were drawn on May 15th, 18th and 21st, 1901, are of special interest, as bearing on the spring "outflush" of solids. This appears to be a dislodgment of the suspended matter, which has accumulated in the bed during the winter, by the active development of worms, larvæ, etc., in the warm spring weather.

They gave the following result on analysis:—

Parts per 100,000.	Average.	Number of Estimations.
Incubator test (by smell) - - - - - - - - -	{5 passed 1 doubtful	(6)
Solids in suspension - - - - - - (30·8 to 63·1)	43·6	(6)
Solids by centrifuge (vols.) - - - - - (340·0 to 540·0)	421·0	(6)
Ratio of solids in suspension to centrifuge solids (1 : 8·6 to 1 : 11·8) -	1 : 9·9	(6)

The average figure of 43·6 parts for suspended solids (containing about 50 per cent. of volatile organic matter) is a very remarkable one. The solids from the first three samples were found to be putrescent, the other three not being tested. At the same time, this matter cannot have been very quickly oxidisable, because the nitrate present in the effluents (the amount of which was not determined) was sufficient to allow of the effluent mixture of liquid and solid withstanding incubation for five days. The above flush-out of solids takes place every year and usually lasts for two or three weeks.

Paper-filtered Effluents.—To further illustrate the influence of the suspended solids upon the figures of analysis, the unsettled effluents Nos. "A" and 3456, drawn in February, 1902, and May, 1904, may be quoted. These gave:—

	No. "A."		No. 3456.	
	Original.	Paper-filtered.	Original.	Paper filtered.
Albuminoid Nitrogen - - - - -	0·28	0·18	0·31	0·10
Total Organic Nitrogen - - - - -	0·95	0·52	0·66	0·18
Oxidized Nitrogen - - - - - -	2·34	2·34	3·16	3·16
Total Nitrogen - - - - - -	4·86	4·39	4·31	3·83
"Oxygen absorbed" at 27° C. *in* 3 *minutes* or *at once*	1·27	0·63	1·01	0·51
,, ,, at 27° C. *in* 4 *hours* - -	3·55	1·98	4·38	—
Solids in suspension (calculated from centrifuge figures).	14·0 ap.	—	14·70	—
Solids by centrifuge (vols) - - - -	167·0	—	124·0	—
Dissolved Oxygen taken up from water in 24 hours at 18° C.	—	—	0·93	0·13

Incubated Samples.—Duplicates of samples Nos. 2911 and 2913 (already referred to) were analysed after being incubated for five days at 27° C., with the results:—

	No. 2911.		No. 2913.	
	Original.	Incubated.	Original.	Incubated.
Ammoniacal Nitrogen - - - - -	0·67	0·71	2·50	2·47
Albuminoid Nitrogen - - - - -	0·09	0·07	0·33	0·28
Total Organic Nitrogen - - - -	0·77	0·46	1·74	1·20
Oxidized Nitrogen - - - - - -	0·63	0·64	0·39	0·0
Total Nitrogen - - - - -	2·07	1·80	4·63	3·65
"Oxygen absorbed" *in* 3 *minutes* at 27° C. -	0·15	0·15	1·55	1·48
,, ,, *in* 4 *hours* - - -	1·33	1·33	4·37	2·15
Solids in Suspension - - - - -	1·70	—	9·80	—

The first of these effluents, which was already fairly well oxidised and contained but little suspended matter, underwent practically no change during the five days' incubation, but the second, which was much less well purified, used up what nitrate it had, without, however, reaching the putrefactive stage.

Exposure of unsettled Effluents to Air.—Duplicates of Nos. 2912 and 2914 were examined, after being kept in open flasks at laboratory temperature for 9 and 5 days respectively. The results of the analyses may be given here; the general effect was beneficial:—

	No. 2912.		No. 2914.	
	Original.	Exposed to Air.	Original.	Exposed to Air.
Ammoniacal Nitrogen - - - - - -	2·47	2·52	0·87	0·84
Albuminoid Nitrogen - - - - - -	0·22	0·15	0·21	0·14
Total Organic Nitrogen - - - - - -	0·85	0·83	0·72	0·61
Oxidized Nitrogen - - - - -	0·71	0·51	0·26	0·29
Total Nitrogen - - - - - - -	4·03	3·86	1·85	1·74
"Oxygen absorbed" *in* 3 *minutes* at 27° C. -	0·74	0·52	0·81	0·48
" " *in* 4 *hours* " -	2·81	1·92	2·66	2·80
Solids in suspension - - - - - -	4·60		7·50	

EFFLUENT SETTLING TANKS.

Number - - 3.

Dimensions and particulars:—

No. 1 - - - - - - - 53 feet 8 inches by 25 feet 9 inch and 2 feet 4½ inches deep.

Capacity - - - - - - - 20,439 gallons.

No. 2 - - - - - - - 54 feet by 25 feet 8 inches and 2 feet 4¾ inches deep.

Capacity - - - - - - - 20,757·5 gallons.

No. 3 - - - - - - - 30 feet 1 inch by 14 feet 5 inches and 4 feet 9 inches deep.

Capacity - - - - - - - 12,893·5 gallons.

Total capacity - - - - - 54,090 gallons.

Construction.—The effluent settling tanks are constructed of brick and cement, with concrete bottoms. They are rectangular in shape and are fitted with scum-boards.

Flow Through.—The flow through the settling tanks is different in each of the three cases, No. 1 tank receiving the effluent from three filters, No. 2 tank from three filters, and No. 3 tank from four filters. The effluent from the four smaller filters settles underneath them in a large shallow tank, which is periodically cleaned out by allowing the deposited solids to run into No. 3 effluent tank.

The rate of flow also varies considerably through each. It is impossible, therefore, to give anything but an approximate idea of the time allowed for settlement. The total effluent settling tank capacity, however (54,090 gallons), is sufficient to allow of about one hour's continuous flow settlement of the effluent in dry weather.

Working.—The effluent settling tanks receive the whole flow of filter effluent day and night, three filters delivering into No. 1 tank, three filters into No. 2 tank, four filters into No. 3 tank, and the remaining four filters as already described. The deposit which collects at the bottom of a tank, as the result of this settlement, is removed once a week by means of a pulsometer. It was originally sent back into the septic tanks; but it is now pumped into lagoons and then mixed with the septic sludge.

For a short time during the latter part of our observations—February 2nd, 1904, to March 15th, 1904—an interesting experiment was carried out by Mr. Newton, for the purpose of ascertaining whether it would be possible to obtain better settlement of the filter effluent by adding a precipitant to it as it passed into the effluent settling tanks.

This consisted in the addition of 1 cwt. of alumino-ferric per day for the whole of the filter effluent. The experiment appears to have given satisfactory results, both the suspended solids and the albuminoid ammonia having been considerably reduced in the final effluent.

The figures for the above experiment are given in Table 3 of Mr. Newton's report for the year ending March 31st, 1905.

Settled Effluents. Hourly Samples.—Three hourly sets of settled effluent, Nos. 2896, 2897 and 2900 were examined. The first two of these were drawn in dry weather at the end of August, 1900, and represented 72 hours' flow*; they were taken respectively from four old filters and from six new ones. Their figures of analysis are, however, to all intents and purposes identical, excepting as regards suspended solids (6·1 parts from the old filters and 1·8 from the new), and hence in the appended table they are averaged together as one sample. The remaining hourly set, No. 2900, represents 48 hours' flow of the effluent from the six new filters in the middle of October, 1900. For purposes of comparison, the average figures of the two corresponding sets of septic tank liquor, Nos. 2895 and 2899, are also given here:—

Parts per 100,000.		Settled Effluents Nos. 2896, 2897 and 2900.	Septic Tank Liquors Nos. 2895 and 2899.
Ammoniacal Nitrogen	(0·68 and 0·47)	0·58	5·11
Albuminoid Nitrogen	(0·05 and 0·06)	0·06	0·32
Total Organic Nitrogen	(1·21 and 0·60)	0·90	1·48
Oxidized Nitrogen	(2·69 and 1·71)	2·20	
Total Nitrogen	(4·59 and 2·78)	3·68	6·58
"Oxygen absorbed" *in* 3 *minutes* at 27° C.	(1·24 and 0·15)	0·70	1·86
,, ,, *in* 4 *hours* ,,	(4·30 and 1·08)	2·69	8·61
Incubator Test (Scudder)		Passed	
Incubator Test (by smell)		Passed	
Solids in suspension	(4·0 and 3·2)	3·60	21·10
Iron in solution	(0·10 and 0·10)	0·10	0·67

These settled effluents thus show a reduction in figures, as compared with the corresponding septic tank liquors, of—

	Per cent.
Total Nitrogen	46
Albuminoid Nitrogen	81
"Oxygen absorbed" in 4 hours	69
Solids in suspension	83

They may be described as well oxidized effluents of good quality, though the settlement of the suspended matter might perhaps have been carried further, with advantage. In general character they were of course similar to the other effluents which have been already described in some detail.

Settled Effluents.—Chance Samples.—Fourteen chance samples of settled effluents were examined chemically, viz., Nos. 2392, 2393, 2902, 2906, 2907, 2908, 2909, 2910, 2327B, 2930, 3057B, 3086C, 522 and 3423. These were drawn at irregular intervals between July, 1900 and March, 1904, in very varying weather, but three-fourths of them in the cooler months of the year.

* The fractions from 2 a.m. to 5 a.m. were omitted each day.

The following figures were obtained :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(0·35 to 2·12)	0·91	(11)
Albuminoid Nitrogen	(0·08 to 0·30)	0·16	(11)
Total Organic Nitrogen	(0·12 to 1·51)	0·80	(7)
Oxidized Nitrogen	(0·69 to 3·01)	1·69	(14)
Including Nitrous Nitrogen	(0·0 to 0·15)	0·07	(12)
Total Nitrogen	(1·79 to 4·34)	3·34	(8)
"Oxygen absorbed" *at once* * at 27° C. (80° F.)	(0·15 to 1·00)	0·47	(11)
" " *in* 4 *hours*	(1·25 to 3·59)	2·36	(13)
Incubator Test (Scudder)†		{ 9 passed 2 just failed.	(11)
Incubator Test (by smell)		13 passed.	(13)
Smell when drawn		6 good.	(6)
Smell when analysed		4 good.	(4)
Chlorine	(5·72 to 8·72)	6·95	(3)
Solids in Suspension	(4·40 to 6·58)	5·49	(4)
Solids by Centrifuge (Vols.)	(37·0 to 83·0)	55·0	(6)
Ratio of Solids in Suspension to Centrifuge Solids	(1 : 7·9 to 1 : 11·2)	1:9·3	(3)
Dissolved Oxygen taken up *in* 24 *hours* at about 18°C.‡	(0·0 to 1·21 ap.)	0·48 ap.	(4)
	c.c. (*per litre.*)		
Oxygen in Solution when analysed	(2·0 ap. to 5·3)	4·0 ap.	(4)

These effluents had of course the same physical characteristics as the unsettled samples, excepting that they contained less suspended matter, this being of a flocculent nature. Although only noted in a few instances, the liquid portion of the effluent was probably in every case fairly clear, but of a slight brownish tint. All the samples had a clean smell, both when drawn and when analysed, while nearly all of them were well nitrated and they all withstood the incubator test. The suspended solids were determined gravimetrically in four samples and the centrifuge muds in six. If we take those centrifuge results as representative of the whole of the effluents, then the suspended solids would average about 6 parts, as against 20 parts in the hourly and 9 parts in the chance samples of unsettled effluent. The settlement of solids from the effluents is thus capable of being considerably improved at Accrington. In five instances the suspended matter was found to be putrescent, and it may safely be inferred that this would have applied in every case.

The final effluents may thus be described, generally, as being well nitrated effluents of good quality, but requiring a further separation of the suspended matter present.

Compared with the three sets of hourly samples of sewage and the seven sets of hourly samples of septic tank liquor, the above chance samples of settled effluent show the following reduction in figures (the numbers in brackets indicate the estimations in each case) :—

Compared with	Sewage.	Septic Tank Liquor.
Calculated on :—		
Total Nitrogen	50 per cent.	(8) 51 per cent. reduction.
Ammoniacal Nitrogen	78 "	(11) 82 " "
Albuminoid Nitrogen	75 "	(11) 53 " "
Total Organic Nitrogen	68 "	(7) 56 " "
"Oxygen absorbed" in 4 *hours*	80 "	(13) 73 " "
Solids in Suspension	80 " approx.	(6) 70 " approx.

* Samples 2902 to 2910 *in* 3 *minutes*.
† The Nitrite after incubation was not determined in samples 2902 to 2910.
‡ In two cases at laboratory temperature.

Comparing those reduction figures with the similar ones given by the chance samples of unsettled effluent, the superiority of the settled effluents is apparent. More nitrate was also found in the latter, a circumstance no doubt due in some degree to the partial removal of solids capable of taking up either dissolved oxygen or oxygen from nitrate.

The effect of removing the suspended solids from an effluent by paper filtration is well seen in the case of No. 2927 B., thus :—

	Original Effluent.	After Filtration through Paper.
Albuminoid Nitrogen - - - - - - -	0·19	0·10
Oxidized Nitrogen - - - - - - - -	2·24	2·24
"Oxygen absorbed" in 4 *hours at* 27° C. - - -	3·11	1·75
Solids in Suspension (calculated from centrifuge figure)	9·0 approximate.	—
Solids by Centrifuge (vols.) - - - - - -	83·0	—

Three duplicates of the settled effluents Nos. 2902, 2907 and 2909, besides being examined when drawn, were also analysed after being incubated for seven days at 27°C. (80°F.). Contrasting some of their *average* figures with the *average* figures of the original samples, we get :—

	Original Samples.	Incubated Samples.
Ammoniacal Nitrogen - - - - - - -	1·07	1·07
Albuminoid Nitrogen - - - - - - - -	0·14	0·19
Oxidized Nitrogen - - - - - - - -	1·05	0·46
'Oxygen absorbed" in 3 *minutes at* 27° C. - - - -	0·42	0·42
,, ,, in 4 *hours* ,, ,, - - - -	2·11	1·56
Solids in Suspension - - - - - - - -	Not Estimated.	Not Estimated.

The main result of the incubation, therefore, was the reduction of the oxidized nitrogen by only 0·6 part and of the four hours' "Oxygen absorbed" figure by the same amount, a proof that the effluents were already, on the average, well oxidised.

The three samples, Nos. 2906, 2908 and 2910, were similarly examined in duplicate, after being exposed to air and light in large flasks for 14, 11 and 5 days respectively. The *average* figures of their analysis compare with the *average* figures of the original samples, as follows :—

	Original Effluents.	After exposure to air.
Ammoniacal Nitrogen - - - - - - - - -	0·94	0·37
Albuminoid Nitrogen - - - - - - - - -	0·12	0·11
Oxidized Nitrogen - - - - - - - - - -	0·94	1·11
"Oxygen absorbed" *in* 3 *minutes at* 27° C. (80° F.) - - - -	0·27	0·22
,, ,, *in* 4 *hours* ,, ,, - - - - -	2·01	2·01
Solids in suspension - - - - - (4·40 in No. 2910)		Not Estimated.

One effect of the exposure to air was thus to oxidize two-thirds of the ammonia of the original effluents.

Bacteriological Notes.—The bacteriological results are given in Appendix A. Not many samples of sewage or of septic tank liquor were examined bacteriologically, but a large number of effluents were submitted to bacteriological examination at the wish of the Commission. The samples of sewage and septic liquor yielded on analysis results similar to those usually pertaining to liquids of this kind.

As many as 139 samples of effluent were examined bacteriologically, and there can be no doubt that the effect of the treatment was greatly to reduce the number of bacteria originally present. Nearly two-thirds of the samples contained less than 10,000 and nearly one-third less than 1,000 microbes of an intestinal type per c.c. The results as regards the B. enteritidis sporogenes test were, relatively speaking, not so satisfactory; but it has been noted at other places that percolation filters frequently yield proportionately better results with the B. coli test than with the B. enteritidis sporogenes test.

Amount of Septic Tank Liquor treated upon the Accrington Filters.—For the purpose of experiment Mr. Newton has varied the quantities treated upon the filters from time to time. The original filters were run for some time at a rate of approximately 450 gallons per square yard or 150 gallons per cube yard per day, this being considered to be the maximum amount practicable, and all the filters are still as a rule worked at this rate.

They have, however, been tried at rates varying from 230 gallons per square yard or 77 gallons per cube yard per day to considerably over 500 gallons per square yard or 166 gallons per cube yard.

At rates exceeding 500 gallons per square yard per day, the albuminoid ammonia and the suspended solids in the final effluent appear to rise to quantities which are considered too high, and Mr. Newton seems to have concluded that it is inadvisable to work at this rate in dry weather, unless some further means are adopted to deal with the effluent solids. He thinks, however, that in storm times he could with safety treat a quantity in excess of 500 gallons per square yard per day; but as the maximum rates of delivery from the two kinds of sprinkler, as at present used, are equivalent to 523 and 550 gallons per square yard per day, this could not be done without some alteration of the plant.

The average rate of treatment during our observations may be taken to have been between 400 and 450 gallons per square yard, or 133 to 150 gallons per cube yard per day.

In regard to the quantities which might be treated upon the Accrington filters, it may be useful to observe here that the limits of discharge from the *automatic sprinklers*, with the revolving arms perforated as at present, are :—

		Discharge at the rate of :—
At lowest head of water - - - -	3 inches - -	175 gallons per square yard per day.
At highest head of water - - -	24 „ - -	523 „ „ „

The discharge limits of the *pulsometer-fed sprinklers* are :—

		Discharge at the rate of :—
Lowest discharge - - - - -		214 gallons per square yard per day.
Highest discharge - - - - -		550 „ „ „

Effect of Temperature upon the Working of the Accrington Filters.—A good many visits were made during cold weather for the purpose of gaining information upon this point. There was little really very severe weather, however, during the years of observation, and it is, therefore, impossible to state what would have been the result in such a case. We can only say that, during the whole period of observation, neither the working of the filters nor the filter effluent itself was seriously affected by the ordinary frosts and cold weather which prevailed for short periods during the winter months.

A large number of temperature measurements were made by the authorities during the years 1899 and 1900, and we have been allowed to quote from these in this report. The average temperatures through the two years, from measurements made once a day, were as follows :—

TEMPERATURES IN DEGREES FAHRENHEIT.

Year.	Crude Sewage.	Septic Liquor.	Septic liquor as discharging on to filters from the pulsometer-fed sprinklers.	Final filter effluent.
1899.	53·48°	51·99°	59·56°	56·40°
1900.	52·28°	50·70°	56·55°	54·26°

River Water.—In order to test the condition of the Hyndburn river, into which the effluent from the sewage works at Accrington discharges, the following four samples were drawn for analysis on October 3rd, 1901 :—

Parts per 100,000.	No. 2930 Works Effluent.	No. 2931 River Water immediately above effluent outfall.	No. 2932 River Water at Effluent outfall (*i.e.* containing effluent).	No. 2933 River Water 300 yards below Effluent outfall.
Ammoniacal Nitrogen - - - - - -	0·59	0·05	0·09	0·09
Albuminoid Nitrogen - - - - - -	0·12	0·21	0·32	0·21
Total Organic Nitrogen - - - - -	0·77	—	—	—
Nitrous Nitrogen - - - - - - -	0·15	trace	—	—
Nitric Nitrogen - - - - - - -	2·69	trace	heavy trace	trace
Total Nitrogen - - - - - - - -	4·20	—	—	—
Incubator Test (Scudder) - - - - -	passed	failed	failed	failed
„ „ (by smell) - - - - -	passed	failed	failed	failed
Solids in Solution - - - - - - -	66·00	66·16	64·00	66·56
Solids in Suspension - - - - - -	5·36	—	—	—
Solids by Centrifuge (vols.) - - - - -	60·0	80·0	80·0	104·0

When drawn, the above samples of water had an unpleasant soapy smell and the bed of the river was in a dirty condition both above and below the outfall. The figures of analysis

are sufficient to show the very unsatisfactory state of the river at this time. All three samples of river water contained comparatively large quantities of suspended solids, as judged by the centrifuge figures, and all three became putrid upon incubation.

SUMMARY.

The Accrington sewage, which is domestic in character, is distinctly strong in every respect and contains a large quantity of suspended solids. In wet weather it falls to about average or less than average strength, although the solids are apparently never reduced to a low figure. The reasons for the comparative strength of the sewage are (1) that in dry weather the water closets are flushed with waste water, *i.e.*, water which has been already used for household purposes, and (2) that the contents of some 2,000 pails are flushed into the sewers daily. It is thought that not a great deal of subsoil water gains access to the sewers. Were it not for the fact that a large part of the rain which falls upon the area draining to the works is taken into the sewers during wet weather, the Accrington sewage would be a very strong one.

There are no grit chambers in use at Accrington.

The septic tanks are large, open, rectangular ones, averaging between 8 feet 6 inches and 9 feet in depth, with very little slope from inlet to outlet end. During the greater part of the observations these tanks were used in two series of three each, the larger proportion of sludge necessarily collecting in the first tank of a series, which therefore required to be cleaned out more frequently than the others. As a rule the first tank of a series ran for eight months and the second and third for twelve months. Originally the whole of the tanks were used in one series of six, the liquid being thus given about seven hours in dry weather to pass through each tank. We understand, however, that this method of working resulted in the issuing liquid containing large quantities of suspended matter, because of the rather rapid rate of flow. By altering the system to two series of three tanks each, the rate of flow was reduced to one-half and the suspended matter in the liquor considerably lessened. But, as the analyses show, it still remained high, the hourly samples of septic tank liquor giving an average of about 19 parts of suspended solids per 100,000.

A subsequent further modification in the working of the tanks was introduced by Mr. Newton at the close of our observations—a modification which we think distinctly advantageous. One tank is now always kept as a reserve, while the other five are worked in two series as before, but with the first tank of the five serving as a preliminary one for both of the succeeding pairs. By this procedure the empty tank constitutes a reserve for storm water, and therefore a safeguard against very rapid changes in the rate of flow through the other tanks, while at the same time the first flush of a storm water (*i.e.*, the worst part of it) receives in this way quiescent settlement. Judging from some later analyses which we have made for a different object, this alteration in the method of working the tanks, taken together with the rather frequent sludging now practised, has materially lessened the quantity of suspended matter issuing in the septic tank liquor; indeed, we understand that this improvement in the tank liquor was observed before any change was made in the sludging.

The septic tank liquor which the filters at Accrington have to treat is strong organically, and at the time when the observations were made for the Commission it contained an exceptionally large quantity of black flocculent matter in suspension.

The sludge from the tanks is run into lagoons and allowed to dry naturally. It requires about three months in dry weather and up to six months in wet, before the sludge becomes sufficiently consolidated to be spadeable, when it is transferred to barges. The drying process is therefore a very slow one and it gives rise to considerable local smell.

The laboratory experiment with sludge taken from one of the preliminary tanks resulted in a long-continued evolution of gas, when the sludge was kept under practically anaerobic conditions. The decomposition of the solids had thus by no means been carried to its fullest extent in the tank itself; but whether it would be worth while at Accrington, from a practical point of view, to provide extra tank capacity in order to carry this decomposition further, seems doubtful. During our observations an average of about 3,000 tons of wet sludge, containing about 90 per cent. of water, were removed annually from the works. Although this figure was low as compared with the sludge production by the old precipitation process, it still meant a large amount of sludge to be dealt with.

The construction of the filters is simple and the octagonal form tends to economy of space. The semi-open walls and the false bottom allow of good æration and we think that they may both be looked upon as structurally durable. On one occasion, it is true, the wall of a filter gave way, but this was probably because it had been built upon made ground.

The filtering material is of large size (2 inches to 4 inches in diameter), twelve of the filters being of coke and two of clinker. From the fact of none of the beds having clogged, the size of the material appears to be well adapted for the purification of the liquor to be treated. There is no evidence of serious disintegration, either of the coke or the clinker, excepting at the surface where it has been trodden upon. The filters have now been in operation (January 1906) for periods ranging from three and a half to seven and a half years, have treated on the average septic tank liquor at the rate of about 150 gallons per cube yard or 450 gallons per square yard per 24 hours, and they still appear to be in practically as good condition as when they were started. Although we have not specially investigated the point ourselves, there seems to be no material difference in the quality of the effluents from the two kinds of filter.

The three systems of distribution in use at Accrington all act satisfactorily, but the rotating sprinklers give, perhaps, a rather better division of liquid than the stationary distributor, and the effluent from the sprinkler beds, we are informed by Mr. Boothman, is also as a rule the more highly oxidised. The stationary distributor, too, is more expensive both as regards cleaning and renewal, because of the number of the arms and the rusting of the stationary joints. With regard to the two varieties of sprinkler themselves—one driven by a pulsometer and the other working by head of water alone—there appears to be no appreciable difference with regard to quality of effluent, but the cost of running one pulsometer amounts to a large annual sum (approximately £90).

The effluents as they emerge from the filters contain unusually large quantities of suspended solids, which are, however, brown in colour and well coagulated—a good sign. The average hourly samples of unsettled effluent had 20 parts and the ordinary chance samples 9 parts of these solids, while the five chance samples which were drawn when the spring "outflush" of solids from the filters was taking place contained as much as 43·6 parts on the average (maximum figure 63·1 parts). A large portion of this suspended matter is deposited in the effluent setting tanks; thus, in the hourly samples of settled effluent the suspended solids had been reduced to 3–4 parts and in the chance samples to 5–6 parts per 100,000. The comparative analyses of the *whole* effluents, before and after incubation, and the examination of the suspended matter by itself showed that, while those solids were putrescible, they were not of a rapidly putrefactive nature. Still, they would certainly give rise to a nuisance if allowed to accumulate in the bed of a stream. It would therefore be desirable to settle them out still further from the effluents.

No effluent from Accrington which we have examined, even including its suspended solids, has been found to be putrescent upon incubation for 5 days. The liquid portion has as a rule been bright, and the effluents have always had a clean smell both when drawn and when analysed. The nitration relatively to the total nitrogen present has usually been good. Apart, therefore, from the question of suspended solids, the Accrington effluents proved very satisfactory from a chemical point of view, especially after the four last filters had been added, and they also usually showed a remarkable diminution in the number of microbes, as compared with the original tank liquor. It will be remembered that the filters never treat more than twice the dry-weather flow of tank liquor at any time. Accrington, therefore, furnishes another instance of the comparatively uniform results obtained when the volume treated is only allowed to vary within moderate limits. The fact that not more than twice the dry-weather flow is ever filtered is practical proof that the authorities consider this quantity to be somewhere near the limit, beyond which it is not advisable to go.

As the filters become older, the quantity of suspended matter in the effluents appears to increase, but the liquid portion of the effluent shows no deterioration. Owing to the continual variations in the amounts of suspended solids issuing from the filters, it is impossible to say when an equilibrium will be established between the quantities going on and coming out, but we have no doubt that there will be an equilibrium in course of time.

With a view of testing the effect of the effluent upon the water of the river Hyndburn, into which it flows, samples of the river water were upon one occasion collected above and below the works. The analyses, however, showed these samples to contain large quantities of suspended matter and to be putrescent, the effluent itself being non-putrescent.

There is frequently considerable smell from the waterfall of tank liquor between the first and second tanks, from the sprinkling of the septic tank liquor, and also from the sludge lagoons. But, as the works are situated in a hollow and as they are some distance away from any houses excepting that of the manager, it may be said that there is no nuisance from them of a public character.

We wish, in conclusion, to express our indebtedness to Mr. W. J. Newton, Borough Surveyor of Accrington, and to Mr. John Boothman, Chemist and Manager of the Sewage Works, for the invaluable help which they have given us in connection with the work of the foregoing Report.

APPENDIX A.

ACCRINGTON AND CHURCH OUTFALL SEWAGE WORKS.

OPEN SEPTIC TANKS, FOLLOWED BY CONTINUOUS FILTRATION THROUGH COARSE MATERIAL.

Results of the Bacteriological Examination of 139 samples of the Accrington Filter-bed Effluents, together with some samples of Crude Sewage and Open Septic Tank Liquor.

CONTENTS.

A. C. HOUSTON,

July, 1904.

ACCRINGTON OPEN SEPTIC TANKS, FOLLOWED BY CON

RESULTS OF THE BACTERIOLOGICAL EXAMINATIO

1						2		3						4			
Description of the Sample.						Total Number of Bacteria in 1 c.c.		Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method.)						Chief Biological Characters of the *strain* of B Coli present in the number specified in Col. 3.			
No.	Time of Collection.				Other Details.			1	10	100	1,000	10,000	100,000	Gas.	Indol.	(a) Acidity (b) Clot. (Litmus milk cultures, days at 37° C.)	
	Hour.	Day.	Month.	Year.		Gelatine at 20° C.	Agar at 37° C.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	(Gelatine shake cultures, 24 hrs. at 20° C.)	(Broth cultures, 5 days at 37° C.)	(a)	(b)
					ACCRINGTON EFFLUENTS.												
1	12.15 p.m.	19	2	1902	Effluent from Filters I. & II. unsettled.												
2	"	"	"	"	Effluent from Filters 7, 8, & 9 unsettled.												
3	—	11	5	"	Effluent from Filters 7, 8, & 9 ..	600,000	110,000						+	+	—	+	—
4	—	12	"	"	Effluent from Filters 7, 8, & 9 ..	1,600,000	280 000				+	—		+	—	+	+
5	—	13	"	"	Effluent from Filters 7, 8, & 9 ..	2,900,000	440,000					+	—	+	+	+	+
6	—	19	"	"	Effluent from group of Beds 1, 2, & 3.	3,100,000	52,000			—							
7	—	20	"	"	Effluent from group of Beds 1, 2, & 3.	3,600,000	400,000						+	+	+	+	+
8	—	21	"	"	Effluent from group of Beds 1, 2, & 3.	2,600,000	130,000						+	+	+	+	+
9	—	26	"	"	Effluent from Beds 5, 5A, 6, 6A	2,600,000	57,000			+	—			+	+	+	+
10	—	27	"	"	Effluent from Beds 5, 5A, 6, 6A	3,700,000	360,000						+	+	+	+	—
11	—	28	"	"	" " " " " "	3,200,000	130,000					+	—	+	+	+	+
12	—	1	6	"	Effluent from Beds 7, 8, & 9 ..	370,000	12,000					+	—	+	+	+	—
13	—	2	"	"	" " " " " ..	270 000	13,000				+	—		+	—	+	—
14	—	3	"	"	" " " " " ..	65,000	7,500			+	—			+	+	+	+
15	—	9	"	"	Effluent from Beds 10, 11, & 12..	1,100,000	79,000				+	—		+	+	+	+
16	—	10	"	"	" " " " "	3,300,000	620,000			+	—			+	+	+	+
17	—	11	"	"	" " " " "	3,700 000	570,000				+	—		+	—	+	—
18	—	16	"	"	Effluent from Beds 1, 2, & 3 ..	150,000	3,300	+	—					+	+	+	+
19	—	17	"	"	" " " " " ..	3,200,000	110,000				+	—		+	+	+	+
20	—	18	"	"	" " " " " ..	3,000 000	260,000			+	—			+	+	+	+
21	—	30	"	"	Effluent from Beds 5, 5A, 6, 6A		85,000										
22	—	1	7	"	" " " " "		28,000										
23	—	2	"	"	" " " " "		340,000										

...OUS FILTRATION THROUGH COARSE MATERIAL.

...HE ACCRINGTON FILTER BED EFFLUENTS.

5					6						7						8	
Indol Test. ...dol in broth cultures direct (5 days at 37° C).					B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anaerobic milk cultures). Cultures heated to 80° C. for 10 minutes.						Bile-Salt Glucose Peptone Test. (+ = acid and gas.) 48 hours at 37° C.						No.	REMARKS.
...0 ...1 ...c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.		
							+	—									1	Samples 1 and 2 yielded "gas" in gelatine "shake" cultures within 24 hours at 20° C. with ·01 and ·1 c.c. respectively.
							+	—									2	Samples 1 and 2 gave a positive result with the neutral red broth test with ·0001 c.c.
			+	—													3	
			+	—													4	
				+													5	
			+	—													6	
				+													7	
				+													8	
		+	—														9	
			+	—													10	
			+	—													11	
			+	—													12	
				+													13	
			+	—													14	
			+	—													15	
		+	—														16	
			+	—													17	
[illegible]	—																18	
		+	—														19	
			+	—													20	
	+	—															21	
	+	—															22	
		+	—														23	

RESULTS OF THE BACTERIOLOGICAL EXAMINATION

1						2		3						4			
Description of the Sample.						Total Number of Bacteria in 1 c.c.		Number of B. Coli (or closely allied forms) in 1 c.c.						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection.				Other Details.									Gas.	Indol.	(a) Acidity (b) Clot. (Litmus milk cultures, 5 days at 37° C.)	
	Hour.	Day.	Month.	Year.		Gelatine at 20° C.	Agar at 37° C.	1 — 1 c.c.	10 — ·1 c.c.	100 — ·01 c.c.	1,000 — ·001 c.c.	10,000 — ·0001 c.c.	100,000 — ·00001 c.c.	(Gelatine "shake" cultures, 24 hrs. at 20° C.)	(Broth cultures 5 days at 37° C.)	(a)	(b)
					ACCRINGTON EFFLUENTS.												
24	—	7	7	1902	Filter Effluent from Beds 7,8, & 9		510,000										
25	—	8	,,	,,	,, ,, ,, ,, ,,		520,000										
26	—	9	,,	,,	,, ,, ,, ,, ,,		740,000										
27	—	14	,,	,,	Effluent from Beds 10, 11, & 12		120,000										
28	—	15	,,	,,	,, ,, ,, ,, ,,		1,100,000										
29	—	16	,,	,,	,, ,, ,, ,, ,,		950,000										
30	—	28	,,	,,	Effluent from Beds 1, 2, 3. & 4..		1,900,000										
31	—	29	,,	,,	,, ,, ,, ,,		3,700,000										
32	—	30	,,	,,	,, ,, ,, ,,		1,600,000										
33	—	4	8	,,	Effluent from Beds 5, 5A, 6, 6A		9,000										
34	—	5	,,	,,	,, ,, ,, ,,		1,700,000										
35	—	6	,,	,,	,, ,, ,, ,,		2,900,000										
36	—	11	,,	,,	Effluent from Beds 7, 8, & 9..		450,000										
37	—	12	,,	,,	,, ,, ,, ,,		890,000										
38	—	13	,,	,,	,, ,, ,, ,,		510,000										
39	—	18	,,	,,	Effluent from Beds 10, 11 & 12..		30,000										
40	—	19	,,	,,	,, ,, ,, ,,		40,000										
41	—	20	,,	,,	,, ,, ,, ,,		210,000										
42	—	25	,,	,,	Effluent from Beds 1, 2, 3, & 4..		1,000,000										
43	—	26	,,	,,	,, ,, ,, ,,		140,000										
44	—	27	,,	,,	,, ,, ,, ,,		180,000										
45	—	1	9	,,	Effluent from Beds 5, 5A, 6, 6A		2,800,000										
46	—	2	,,	,,	,, ,, ,, ,,		2,600,000										
47	—	3	,,	,,	,, ,, ,, ,,		1,800,000										
48	—	8	9	1902	Effluent from Beds 7, 8, & 9..	80,000	34,000										

[T]HE ACCRINGTON FILTER BED EFFLUENTS—(*Continued*).

5					6						7						8	
Indol Test. [In]dol in broth cultures direct (5 days at 37° C).					B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anaerobic milk cultures). Cultures heated to 80° C. for 10 minutes.						Bile-Salt Glucose Peptone Test. (+ = acid and gas.) 48 hours at 37° C.						No.	REMARKS.
[1]0	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000		
·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.		
							+	—									24	
								+	—								25	
							+	—									26	
							+	—									27	
							+	—									28	
					+	—											29	
						+	—										30	
						+	—										31	
							+	—									32	
					+	—								+	—		33	
						+	—							+	—		34	
							—								+	—	35	
							+	—						+	—		36	
						+	—						+	—			37	
						+	—							+			38	
						+	—						+	—			39	
					+	—								+	—		40	
						+	—							+	—		41	
							+	—						+	—		42	
								+	—						+	—	43	
					+	—								+	—		44	
						+	—								+	—	45	
						+	—								+	—	46	
						+	—								+	—	47	
							+	—						+	—		48	

RESULTS OF THE BACTERIOLOGICAL EXAMINATION

1						2		3						4			
Description of the Sample.						Total Number of Bacteria in 1 c.c.		Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method.)						Chie. Biological Cha ters of the *strain* o Coli present in th number specified Col. 3.			
No.	Time of Collection.				Other Details.									Gas.	Indol.	(a) Acid (b) Clo (Litmusn cultures days a 37° C.)	
	Hour.	Day.	Month.	Year.		Gelatine at 20° C.	Agar at 37° C.	1 — 1 c.c.	10 — ·1 c.c.	100 — ·01 c.c.	1,000 — ·001 c.c.	10,000 — ·0001 c.c.	100,000 — ·00001 c.c.	(Gelatine "shake" cultures, 24 hrs. at 20° C.)	(Broth cultures, 5 days at 37° C.)	(a)	(
					ACCRINGTON EFFLUENTS.												
49	—	9	9	1902	Effluent from Beds 7, 8, & 9 ..	80,000	39,000										
50	—	10	,,	,,	,, ,, ,, ,,	10,000,000	3,300,000										
51	—	15	,,	,,	Effluent from Beds 10, 11, & 12..	120,000	30,000										
52	—	16	,,	,,	,, ,, ,, ,,	1,600,000	1,300,000										
53	—	17	,,	,,	,, ,, ,, ,,	2,300,000	210,000										
54	—	22	,,	,,	Effluent from Beds 1, 2, 3, & 4..	260,000	46,000										
55	—	23	,,	,,	,, ,, ,, ,,	660,000	310,000										
56	—	24	,,	,,	,, ,, ,, ,,	1,400,000	260,000										
57 .. .	—	29	,,	,,	Effluent from Beds 5, 5A, 6, 6A	10,000,000	480,000										
58	—	30	,,	,,	,, ,, ,, ,,	360,000	49,000										
59	—	1	10	,,	Effluent from Beds 5, 5A, 6, 6A	16,000,000	1,800,000										
60	—	6	,,	,,	Effluent from Beds 7, 8, & 9 ..	14 000,000	1,500 000										
61	—	7	,,	,,	,, ,, ,, ,, ,, ..	20,000,000	2,600,000										
62		8	,,	,,	,, ,, ,, ,, ,, ..	8,000,000	1,100,000										
63		13	,,	,,	Effluent from Beds 10, 11, & 12 ..	2,000,000	400,000										
64	—	14		,,	,, ,, ,, ,, , ..	100,000	5,000										
65	—	15	,,	,,	,, ,, ,, ,, ,, ..	3,500,000	100,000										
66	–	20	,,	,,	Effluent from Beds 1, 2, 3, & 4 ..	8,900,000	140,000										
67	—	21	,,	,,	,, ,, ,, ,, ,, ..	4,800,000	730,000										
[illegible]	—	22	,,	,,	,, ,, ,, ,, ,, ..	1,600,000	120,000										
69	—	27	,,	,,	Effluent from Beds 5, 5A, 6, 6A..	2,100,000	80,000										
70	—	28	,,	,,	,, ,, ,, ,, ,, ..	2,300,000	140,000										
71	—	29	,,	,,	,, ,, ,, ,, ,, ..	1,700,000	280,000										
72	—	3	11	,,	Effluent from Beds 7, 8, & 9 ..	170,000	42,000										
73	—	4	,,	,,	,, ,, ,, ,, ,, ..	3,400,000	530 000										

HE ACCRINGTON FILTER BED EFFLUENTS—(*Continued*).

5					6						7						8	
Indol Test. ndol in broth cultures direct (5 days at 37° C).					B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						Bile-Salt Glucose Peptone Test. (+ = acid and gas.) 48 hours at 37° C.						No.	REMARKS.
0	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000		
1 .c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.		
							+	—						+	—		49	
							+	—								+	50	
						+	—										51	
							+	—									52	
								+	—								53	
						+	—							+	—		54	
							+	—						+	—		55	
						+	—							+	—		56	
								+	—						+	—	57	
							+	—						+	—		58	
							+	—								+	59	
							+	—							+	—	60	
							+	—							+	—	61	
							+	—								+	62	
						+	—							+	—		63	
							+	—						+	—		64	
							+	—						+	—		65	
						+	—							+	—		66	
						+	—							+	—		67	
						+	—							+	—		68	
						+	—								+	—	69	
							+	—							+	—	70	
								+	—						+	—	71	
							+	—						+	—		72	
							+	—								+	73	

1						2		3						4			
Description of the Sample.						Total Number of Bacteria in 1 c.c.		Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method.)						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection.				Other Details.									Gas.	Indol.	(a) Acidity. (b) Clot. (Litmus milk cultures, 5 days at 37° C.)	
	Hour.	Day.	Month.	Year.		Gelatine at 20° C.	Agar at 37° C.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	("Gelatine" shake cultures, 24 hrs. at 20° C.)	(Broth cultures, 5 days at 37° C.)	(a)	(b)
74	—	5	11	1902	Effluent from Beds 7, 8, & 9 ..	2,600,000	460,000										
75	—	10	,,	,,	Effluent from Beds 10, 11, & 12 ..	170,000	9,000										
76 .. .	—	11	,,	,,	,, ,, ,, ,, ,, ..	3,800,000	72,000										
77	—	12	,,	,,	,, ,, ,, ,, ,, ..	180,000	14,000										
78	—	17	,,	,,	Effluent from Beds 1, 2, 3, & 4 ..	1,000,000	290,000										
79	—	18	,,	,,	,, ,, ,, ,, ,, ..	3,200,000	710,000										
80	—	19	,,	,,	,, ,, ,, ,, ,, ..	800,000	240,000										
81 (3057)	3.55 P.M.	,,	,,	,,	Final Effluents from Beds 7, 8, & 9 Chance sample, strong E. wind and cold								+	+	—	+	+
82	—	24	,,	,,	Effluent from Beds 7, 8, & 9 ..												
83	—	25	,,	,,	,, ,, ,, ,, ,, ..												
84	—	26	,,	,,	,, ,, ,, ,, ,, ..												
85	—	1	12	,,	Filter Effluent from Beds 10, 11, 12		58,000										
86	—	2	,,	,,	,, ,, ,, ,, ,, ..		130,000										
87	—	3	,,	,,	,, ,, ,, ,, ,, .		20,000										
88	—	8	12	,,	Effluent from Beds 1, 2, 3, & 4 ..						+	—		+	+	+	+
89	—	9	,,	,,	,, ,, ,, ,,								+	+	—	+	—
90	—	10	,,	,,	,, ,, ,, ,,						+	—		+	+	+	+
91	—	15	,,	,,	Effluent from Beds 5, 5A, 6, 6A												
92	—	16	,,		,, ,, ,, ,,												
93	—	17	,,	,,	,, ,, ,, ,,												
94	—	29	,,	,,	Effluent from Beds 7, 8, & 9 ..		9,000										
95	—	30	,,	,,	,, ,, ,, ,,		1[illegible],000										
96	—	31	,,	,,	,, ,, ,, ,,		10,000										
97	—	5	1	1903.	Effluent from Beds 10, 11, & 12					+	—			+	+	+	+
98	—	,,	,,	,,	,, ,, ,, ,,					+	—			+	+	+	+

…e Accrington Filter Bed Effluents—(*Continued*).

5											7						8	
Indol Test. …dol in broth cultures direct (5 days at 37° C).					B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						Bile-Salt Glucose Peptone Test. (+ = acid and gas.) 48 hours at 37° C.						No.	REMARKS.
…0 …c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	1 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.		
							+	—						+	—		74	
						+	—						+	—			75	
							+	—						+	—		76	
							+	—					+	—			77	
						+	—								+	—	78	
							+	—							+	—	79	
						+	—									+	80	
				+												+	81 (3057)	Sample (3057) yielded gas in la-tine "shake" cultures within 24 hours at 20° C. with ·01c.c. As regards the Cane-sugar peptone test a positive result was obtained with ·0001 c.c.
								+	—						+	—	82	
							+	—						+	—		83	
							+	—						+	—		84	
							+	—									85	
							+	—									86	
							+	—									87	
			+	—			+	—									88	
			+	—			+	—									89	
		+	—				+	—									90	
						+	—						+	—			91	
							+	—					+	—			92	
							+	—					+	—			93	
						+	—										94	
						+	—										95	
						+	—										96	
		+	—				+	—									97	
	+	—					+	—									98	

RESULTS OF THE BACTERIOLOGICAL EXAMINATIO

1						2		3						4		
Description of the Sample.						Total Number of Bacteria in 1 c.c.		Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method.)						Chief Biological Charac-ters of the *strain* of B. Coli present in the number specified in Col. 3.		
No.	Time of Collection.				Other Details.									Gas.	Indol.	(a) Acid (b) Clo (Litmusm cultures days a 37° C.)
	Hour.	Day.	Month.	Year.		Gelatine at 20° C.	Agar at 37° C.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	("Gelatine" shake" cultures, 24 hrs. at 20° C.)	(Broth cultures, 5 days at 37° C.)	(a)
					ACCRINGTON EFFLUENTS.											
99	—	7	1	1903	Effluent from Beds 10, 11, & 12..					+	—			+	+	+
100	—	12	"	"	Effluent from Beds 1, 2, 3, and 4											
101 (3086b)	3.5 P.M.	12	"	"	Effluent from No. 7 Bed, chance sample, effluent unsettled ..		16.000				+	—		+	—	+
102	—	13	"	"	" " " "											
103	—	14	"	"	" " " "											
104	—	19	"	"	Effluent from Beds 5, 5A, 6, 6A		2 000									
105	—	20	"	"	" " " "		22 000									
106	—	21	"	"	" " " "		16,000									
107	—	26	1	"	Effluent from Beds 7, 8, & 9 ..					—						
108	—	27	"	"	" " " "						+	—		+	+	+
109	—	28	"	"	" " " "						+	—		+	+	+
110	—	2	2	"	Effluent from Beds 10, 11, & 12..											
111	—	3	"	"	" " " "											
112	—	4	"	"	" " " "											
113	—	9	"	"	Effluent from Beds 1, 2, 3, & 4..		20,000									
114	—	10	"	"	" " " "		8,100									
115	—	11	"	"	" " " "		4,900									
116	—	16	"	"	Effluent from Beds 5, 5A, 6, 6A						+	—		+	+	+
117	—	17	2	"	Effluent from Beds 5, 5A, 6, 6A ..					+	—			+	+	+
118	—	18	"	"	" " " " " ..						+	—		+	+	+
119	—	23	"	"	Effluent from Beds 7, 8, & 9 ..											
120	—	24	"	"	" " " " " ..											
121	—	25	"	"	" " " " " ..											
122	—	2	3	"	Effluent from Beds 10, 11, & 12..		9 0									
123	—	3		"	" " " " " ..		1 [illegible]00									

HE ACCRINGTON FILTER BED EFFLUENTS—(*Continued.*)

5				6						7						8	
Indol Test. ol in broth cultures direct (5 days at 37° C).				B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						Bile-Salt Glucose Peptone Test. (+ = acid and gas.) 48 hours at 37° C.						No.	REMARKS.
100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.		
+	—					+	—									99	
						+	—					+	—			100	
+	—				+	—						+	—			101 (3086b)	Sample (3086B) yielded positive results with ·01 c.c. with the neutral red broth and lactose peptone milk tests.
						+	—							+	—	102	
						+	—							+	—	103	
						+	—									104	
					+	—										105	
						+	—									106	
						+	—									107	
	+	—		+	—											108	
	+	—			+	—										109	
					+	—						—				110	
						+	—					+	—			111	
					+	—						—				11	
					+	—										113	
					+	—										114	
					+	—										115	
+	—					+	—									116	
	+	—			+	—										117	
	+	—					+	—								118	
						+	—					+	—			119	
						+	—					+	—			120	
						+	—					+	—			121	
						+	—									122	
					+	—										123	

RESULTS OF THE BACTERIOLOGICAL EXAMINATION

1						2		3						4			
Description of the Sample.						Total Number of Bacteria in 1 c.c.		Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method.)						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection.				Other Details.									Gas.	Indol.	(a) Acidity (b) Clot. (Litmus milk cultures, days at 37° C.)	
	Hour	Day.	Month.	Year.		Gelatine at 20° C.	Agar at 37° C.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	(Gelatine "shake" cultures, 24 hrs. at 20° C.)	(Broth cultures, 5 days at 37° C.)	(a)	(b)
					ACCRINGTON EFFLUENTS.												
124	—	4	3	1903	" " " " " ..		2,400										
125	—	9	"	"	Effluent from Beds 1, 2, 3, & 4 ..												
126	—	10	"	"	" " " " ..												
127	—	11	"	"	" " " " ..												
128	—	16	"	"	Effluent from Beds 5, 5A, 6, 6A ..								+	+	—	Alkali	—
129	—	17	"	"	" " " " " ..					—							
130	—	18	"	"	" " " " " ..					—							
131	—	23	"	"	Effluent from Beds 7, 8, & 9 ..		700										
132	—	24	"	"	" " " " " ..		8,200										
133	—	25	"	"	" " " " " ..		13,000										
134	—	30	"	"	Effluent from Beds 10, 11, & 12												
135	—	31	"	"	" " " " " ..												
136	—	1	4	"	" " " " " ..												
137 (521)..	11 A.M.	22	"	"	Continuous Bed Effluent												
138 (522)..	11.10 A.M.	"	"	"	Continuous Bed Effluent after settlement												
139 (3423)	—	15	3	1904	"Works" Effluent						+	—		+	—	Alkali	—

	Gelatine at 20° C.	Agar at 37° C.	Col. 3	Col. 4
AVERAGES	Average, inclusive of all the results— 3,559,509	Average, inclusive of all the results— 492,389	100,000, 7 samples	21, both indol and clot
	10 million, 5 samples	1 million, 16 samples	10,000, 3 samples	7, neither indol nor c
	1 million 30 samples	100,000, 40 samples	1,000, 13 samples	2, indol, no clot
	100,000, 13 samples	10,000, 27 samples	100, 8 samples	2, clot, no indol
	10,000 3 samples	1,000, 12 samples	1, 1 sample	
		100, 2 samples	Negative 1/100 c.c. 4 samples	

E ACCRINGTON FILTER BED EFFLUENTS.

5				6						7						8	
Indol Test. in broth cultures direct (5 days at 37° C).				B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						Bile-Salt Glucose Peptone Test. (+ = acid and gas.) 48 hours at 37° C.						No.	REMARKS.
100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.		
						+	−									124	
					+	−							+	−		125	
						+	−					+	−			126	
						+	−					+	−			127	
		+	−		+	−										128	
+	−					+	−									129	
−				+	−											130	
						+	−									131	
					+	−										132	
							+	−								1 3	
					+	−						−				134	
						+	−					−				135	
						+	−					−				136	
						+	−									137 (521)	Samples (521) (522), and (3423) yielded as regar's the neutral red broth tests the following results: +·001; +·0001; +·001 c.c respectively.
						+	−									138 (522)	
							+	−					+	−		139 (3423	

5	6	7
000, 5 samples	1,000, 9 samples	100,000, 6 samples
000, 13 samples	100, 62 samples	10,000, 16 samples
000, 10 samples	10, 40 samples	1,000 27 samples
100, 7 samples	1, 6 samples	100, 15 samp'es
10, 1 sample		Negative 1/100 c.c. 5 samples
ative 1/100 c.c. 1 sample		

A. C. HOUSTON,
July 5, 1904.

SEWAGES AND OPE

A few samples only of sewage and tank liquor were examined, in order to afford s

The results were similar to those usually met with in

RESULTS OF THE BACTERIOLOGICAL EXAMINATION

1						2						3		
Description of the Sample.						Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatin plate method.)						Chief Biological Cl ters of the strain Coli present in number specified Col. 3		
No.	Time of Collection. Hour.	Day.	Month.	Year.	Other Details.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	Gas. (Gelatine "shake" cultures, 24 hrs. at 20° C.)	Indol. (Broth cultures, 5 days at 37° C.)	(a) Ac (b) ((Litmu cultu days 37° (a,
A	12.10 P.M.	19	2	1902	Crude sewage									
B	—	11	7	1904	Crude sewage						+	+	+	+
C	—	12	"	"	Crude sewage						+	+	+	+
D	—	13	"	"	Crude sewage						+	+	+	+
E	—	14	"	"	Crude sewage						+	+	+	+
F	12.18 P.M.	19	2	1902	Open septic tank liquor									
3056	3.48 P.M.	19	11	"	Open septic tank liquor						+	+	+	+
3086A	3 P.M.	12	1	1903	Open septic tank liquor					+*	—	+	+	+
520	10.40 A.M.	22	4	"	Open septic tank liquor									
G	—	11	7	1904	Open septic tank liquor						+	+	+	+
H	—	12	"	"	Open septic tank liquor						+	+	+	+
I	—	13	"	"	Open septic tank liquor						+	+	—	+
J	—	14	"	"	Open septic tank liquor						+	+	+	+
342	—	15	3	"	Storm overflow discharge						+	+	—	+

EPTIC TANK LIQUOR.

rtunity of comparison with the large number of samples of the effluents.
riological analysis of sewages and open septic tank liquors.

INGTON CRUDE SEWAGE AND OPEN SEPTIC TANK LIQUOR.

4					5						6						7
Indol Test. dol in broth cultures direct (5 days at 37° C).					B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						Bile-Salt Glucose Peptone Test. (+ = acid and gas.) 48 hours at 37° C.						REMARKS.
0	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	
1 c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	
								+	—								Sample A yielded "gas" in gelatine "shake" cultures within 24 hours at 20° C. with ·01 c.c. and a positive result with the neutral red broth test with ·00001 c.c.
				+				+	—							+	
				+				+	—							+	
				+					+							+	
				+					+							+	
								+	—								Sample F yielded "gas" in gelatine "shake" cultures within 24 hours at 20° C. with ·001 c.c. and a positive result with the neutral red broth test with ·0001 c.c.
				+													Sample 3056 yielded "gas" in gelatine "shake" cultures within 24 hours at 20° C. with ·001 c.c. and a positive result with the neutral red broth test with ·0001 c.e.
			+	—			+	—									Sample 3086A gave a positive result with the neutral red broth test with ·0001 c.c. It contained 500,000 microbes per c.c. (agar. at 37° C).
								+	—								Sample 520 gave a positive result with the neutral red broth test with ·0001 c.c.
				+			+	—								+	
				+		+	—									+	
				+				+	—							+	
				+			+	—								+	
								+	—								Sample 3424 gave a positive result with the neutral red broth test with ·00001 c.c.

SUMMARY.

ACCRINGTON EFFLUENTS.

TOTAL Number of Bacteria in one Cubic Centimetre.

(Gelatine at 20° C.)

51 Samples.

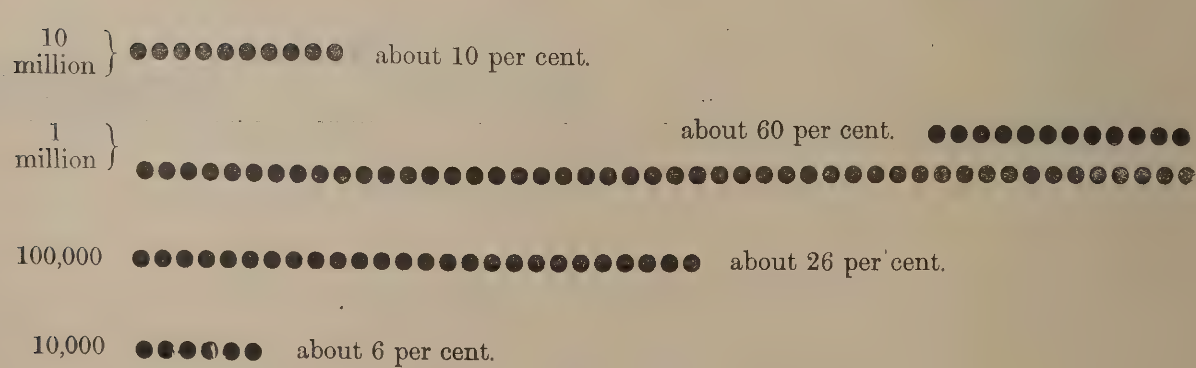
Average number of bacteria per c.c.: over 3 million.

Approximate Figures:

5	samples	(about 10 per cent.)	10 million	bacteria	per c.c.
30	„	(about 60 per cent.)	1 million	„	„
13	„	(about 26 per cent.)	100,000	„	„
3	„	(about 6 per cent.)	10,000	„	„

These results may be shown in a diagram as follows:—*

TOTAL Number of Bacteria (Gelatine at 20° C.)



* Each dot represents one per cent. of the samples.

TOTAL Number of Bacteria in 1 cubic centimetre.

(Agar at 37° C.)

97 Samples.

Average number of bacteria per c.c.: nearly 500,000.

Approximate figures.

16 samples	(about 16 per cent.)	1 million	bacteria per c.c.
40 „	(about 40 per cent.)	100,000	„ „
27 „	(about 27 per cent.)	10,000	„ „
12 „	(about 12 per cent.)	1,000	„ „
2 „	(about 2 per cent.)	100	„ „

These results may be shown in a diagram, as follows:—*

TOTAL Number of Bacteria (Agar at 37° C.).

1 million } ●●●●●●●●●●●●●●●● about 16 per cent.

100,000 ●● about 40 p.c.

10,000 ●●●●●●●●●●●●●●●●●●●●●●●●●●● about 27 per cent.

1,000 ●●●●●●●●●●●● about 12 per cent.

100 ●● about 2 per cent.

---

* Each dot represents one per cent. of the samples.

NUMBER OF B. COLI (OR COLI-LIKE MICROBES) PER C.C.

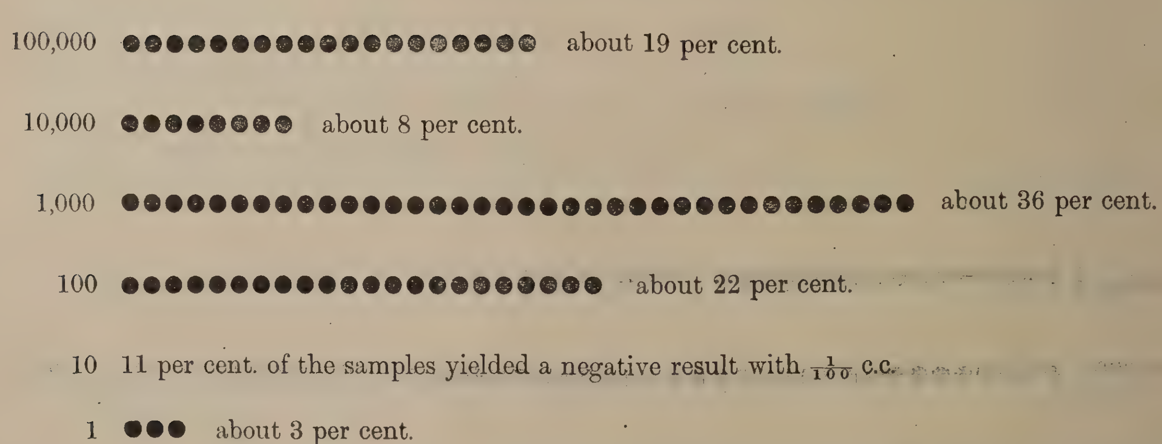
36 Samples.

APPROXIMATE FIGURES.

7	samples	(about 19 per cent.)	100,000 B. coli (or coli-like microbes) per c.c.
3	„	(about 8 per cent.)	10,000 „ „ „
13	„	(about 36 per cent.)	1,000 „ „ „
8	„	(about 22 per cent.)	100 „ „ „
1	„	(about 3 per cent.)	1 „ „ „
4	„	(about 11 per cent.)	Negative result $\frac{1}{100}$ c.c.

These results may be shown in a diagram as follows* :—

B. coli test.



As regards the biological attributes of the B. coli (or coli-like microbes) about 63 per cent. produced both indol in broth culture and acid clot in litmus milk culture. About 33 per cent. were atypical.

---

* Each dot represents one per cent. of the samples.

N.B.—As regards the B. coli, indol, and bile-salt glucose peptone tests, it should be noted that the tests were not "pushed" beyond $\frac{1}{100000}$ of a cubic centimetre.

Indol Test

Indol in Broth Cultures.

(5 days at 37° C.)

37 samples.

Approximate Figures per c.c.

5 samples	(about 13 per cent.)	100,000 (+ ·00001 c.c.)
13 ,,	(about 35 per cent.)	10,000 (+ ·0001 c.c.)
10 ,,	(about 27 per cent.)	1,000 (+ ·001 c.c.)
7 ,,	(about 19 per cent.)	100 (+ ·01 c.c.)
1 ,,	(about 3 per cent.)	10 (+ ·1 c.c.)
1 ,,	(about 3 per cent.)	negative result $\frac{1}{100}$ c.c.)

These results may be shown in a diagram as follows*:

Indol Test.

100,000	●●●●●●●●●●●●●	about 13 per cent.
10,000	●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●	about 35 per cent.
1,000	●●●●●●●●●●●●●●●●●●●●●●●●●●●	about 27 per cent.
100	●●●●●●●●●●●●●●●●●●●	about 19 per cent.
10	●●●	about 3 per cent.

About 3 per cent. yielded a negative result with $\frac{1}{100}$ c.c.

* Each dot represents one per cent. of the samples.

B. Enteritidis Sporogenes Test.

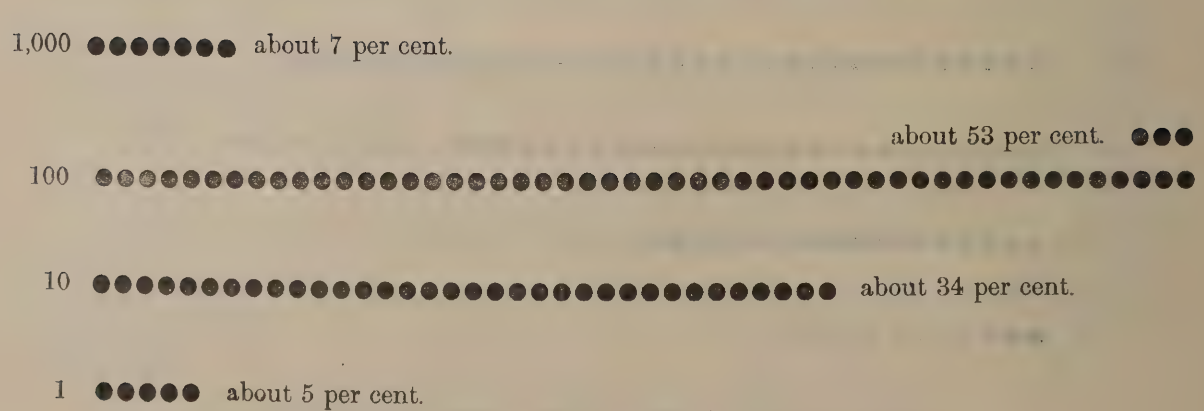
117 Samples.

Approximate Figures per c.c.

9	samples	(about 7 per cent.)	1000 (+ ·001 c.c.)
62	„	(about 53 per cent.)	100 (+ ·01 c.c.)
40	„	(about 34 per cent.)	10 (+ ·1 c.c.)
6	„	(about 5 per cent.)	1 (+ 1 c.c.)

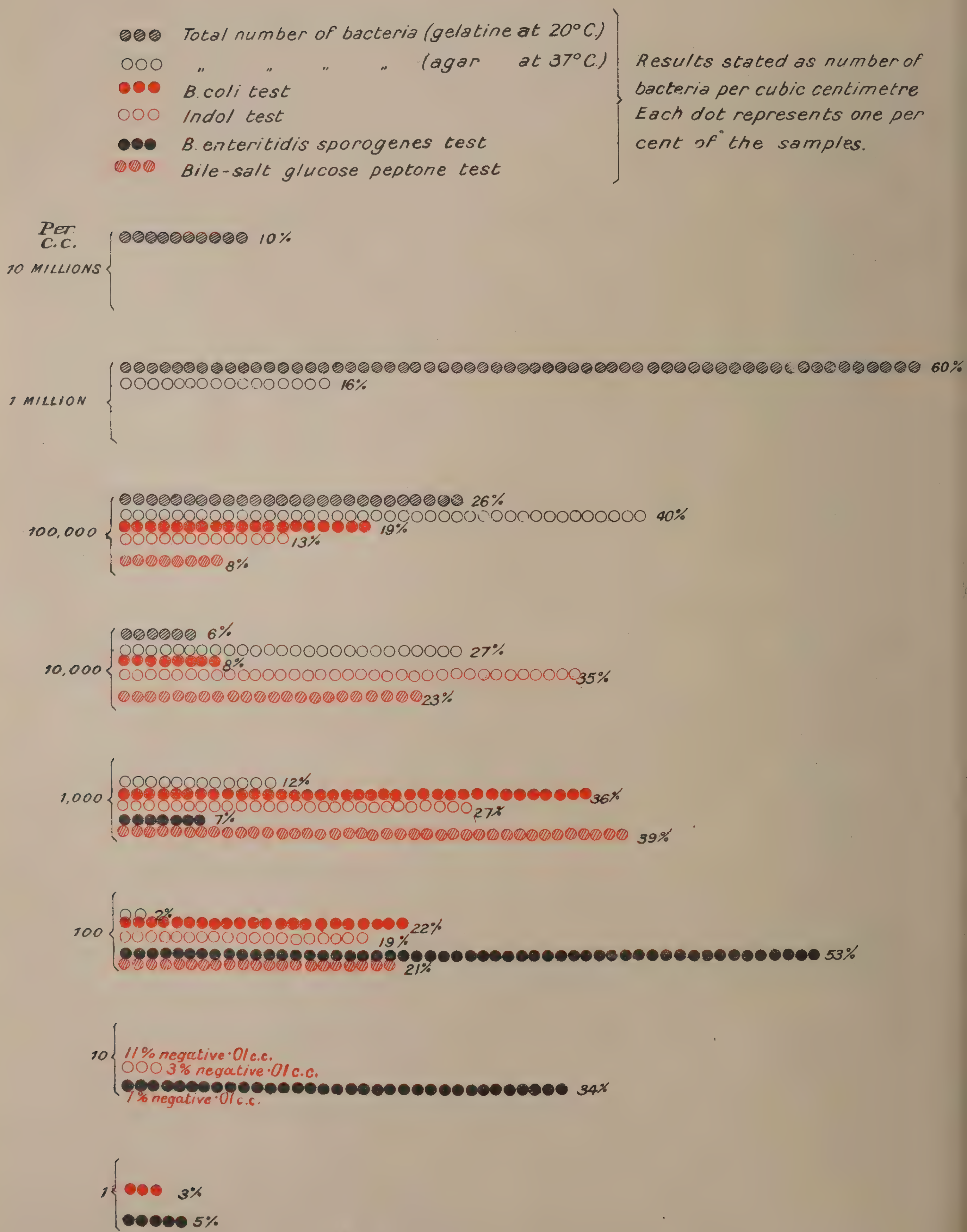
These results may be shown in a diagram as follows:—*

B. Enteritidis Sporogenes Test.



* Each dot represents one per cent. of the samples.

Diagram A. showing the results of the Bacteriological Examination of the Accrington Effluents.



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Weller & Graham, Ltd Litho. London

Bile-Salt Glucose Peptone Test.

69 Samples.

Approximate Figures per c.c.

6	samples	(about 8 per cent.)	100,000	(+ ·00001 c.c.)
16	"	(about 23 per cent.)	10,000	(+ ·0001 c.c.)
27	"	(about 39 per cent.)	1,000	(+ ·001 c.c.)
15	"	(about 21 per cent.)	100	(+ ·01 c.c.)
5	"	(about 7 per cent.)	negative result	$\frac{1}{100}$ c.c.)

These results may be shown in a diagram as follows:—*

Bile-Salt Glucose Peptone Test.

100,000 ●●●●●●●● about 8 per cent.

10,000 ●●●●●●●●●●●●●●●●●●●●●●● about 23 per cent.

1,000 ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●● about 39 per cent.

100 ●●●●●●●●●●●●●●●●●●●●● about 21 per cent.

About 7 per cent. yielded a negative result with $\frac{1}{100}$ c.c.

In Diagram A the foregoing results are grouped together for comparative purposes.

* Each dot represents one per cent. of the samples.

General Remarks.

Although the Accrington effluents were not, in my opinion, in a fit state (bacteriologically) to be discharged into drinking water streams there can be no doubt that the effect of the treatment of the sewage (septic tanks and continuous filtration) was greatly to reduce the number of bacteria originally present.

Taking the B. coli test and the presumptive tests for B. coli and microbes of an intestinal type (indol and bile-salt glucose peptone tests) and considering all these results together, it appears that the effluents contained per cubic centimetre :—

100,000	... ...	13% of the samples	139 Samples Examined.
10,000	... ...	22% „ „	
1,000	... ...	34% „ „	
100	... ...	21% „ „	
Less than 100	... ...	9% „ „	

Hence nearly two-thirds of the samples contained less than 10,000 of these microbes per cubic centimetre.

As regards the B. enteritidis sporogenes test the results per cubic centimetre were :—

1,000	... ...	7% of the samples	139 Samples Examined.
100	... ...	53% „ „	
10	... ...	34% „ „	
1	... ...	5% „ „	

ADDENDUM.

Consideration of the Bacteriological Results in relation to Provisional Standards (Non-drinking water streams).

It is of interest to consider the foregoing results in relation to the primary and secondary standards, which have been suggested tentatively by me in previous reports to the Commission, for effluents destined to discharge into non-drinking water streams. I desire to take this opportunity of once more emphasizing the statement that any standards which I have suggested, whether as regards drinking water streams, non-drinking water streams, potable waters, estuarial waters, or shell-fish are provisional in character, are meant for comparative purposes, and have no administrative significance.

Tests.	Effluents destined to discharge into non-drinking water streams.	
	Primary Standards.	Secondary Standards.
Total number of bacteria (gelatine at 20° C.)	Less than 100,000 per c.c.	Less than 1,000,000 per c.c.
Total number of bacteria (agar at 37° C.)	Less than 10,000 per c.c.	Less than 100,000 per c.c.
B. coli test	Less than 1,000 per c.c. (— ·001 c.c.)	Less than 10,000 per c.c. (— ·0001 c.c.)
Indol test		
Bile-salt glucose peptone test		
Lactose peptone milk test		
Neutral red broth test		
"Gas" test ("gas" in gelatine "shake" cultures, 24 hours at 20° C.)	Less than 10 per c.c. (— ·1 c.c.)	Less than 100 per c.c. (— ·01 c.c.)
B. enteritidis sporogenes test		

Description of Samples and Tests.	Primary Standards.		Secondary Standards.	
	"Passed."	"Rejected."	"Passed."	"Rejected."
Accrington Crude Sewage*:—				
Total number of bacteria (gelatine at 20° C.)	—	—	—	
Total number of bacteria (agar at 37° C.)	—	—	—	—
B. coli test	None out of 4	All	None out of 4	All 4
Indol test	do.	do	do.	do.
Bile-salt glucose peptone test	do.	do	do.	do
Neutral red broth test	One tested failed.		One tested failed.	
"Gas" test ("gas" in gelatine "shake" cultures, 24 hours at 20° C.)	do.		do.	
B enteritidis sporogenes test	None out of 5	All 5	None out of 5	All 5

* These results, although few in number, are given for comparison with the numerous records relating to the effluents.

CONSIDERATION OF THE BACTERIOLOGICAL RESULTS IN RELATION TO PROVISIONAL STANDARDS—*Continued.*

Description of Samples and Tests.	Primary Standards.		Secondary Standards.	
	"Passed."	"Rejected."	"Passed."	"Rejected."
ACCRINGTON OPEN SEPTIC TANK LIQUOR* :—				
Total number of bacteria (gelatine at 20° C.)	—	—	—	—
Total number of bacteria (agar at 37° C.)	1 tested failed		1 tested failed	
B. coli test - - - - - -	None out of 6	All 6	None out of 6	All 6
Indol test - - - - - -	Ditto	Ditto	Ditto	Ditto
Bile-salt glucose peptone test - - -	None out of 4	All 4	None out of 4	All 4
Neutral red broth test - - - -	Ditto	Ditto	Ditto	Ditto
"Gas" test (gelatine "shake" cultures, 24 hours at 20° C.)	Neither of 2	Both	Neither of 2	Both
B. enteritidis sporogenes test - - -	None out of 7	All 7	1 out of 7	6 out of 7
ACCRINGTON STORM OVERFLOW DISCHARGE* :—				
Total number of bacteria (gelatine at 20° C.)	—	—	—	—
Total number of bacteria (agar at 37° C.)	—	—	—	—
B. coli test - - - - -	1 tested failed		1 tested failed	
Indol test - - - - - -	—	—	—	—
Bile-salt glucose peptone test - - -	—	—	—	—
Neutral red broth test - - - -	1 tested failed		1 tested failed	
"Gas" test (gelatine "shake" cultures, 24 hours at 20° C.) -	—	—	—	—
B. enteritidis sporogenes test - - -	1 tested failed		1 tested failed	
ACCRINGTON EFFLUENTS :—				
Total number of bacteria (gelatine at 20° C.)	6%	94%	31%	69%
Total number of bacteria (agar at 37° C.)	14%	86%	42%	58%
B. coli test - - - - - -	36%	64%	72%	28%
Indol test - - - - - - -	24%	76%	51%	49%
Bile-salt glucose peptone test - - -	29%	71%	68%	32%
Neutral red broth test - - - -	1 out of 6	5 out of 6	3 out of 6	3 out of 6
"Gas" test ("gas" in gelatine "shake" cultures, 24 hours at 20° C.)	None out of 3	All 3	1 out of 3	2 out of 3
B. enteritidis sporogenes test - -	5%	95%	39%	61%

* These results, although few in number are given for comparison with the numerous records relating to the effluents.

ANDOVER SEWAGE WORKS

1. Situation of works - - - - -	About $\frac{1}{2}$-mile from the town.
2. Method of treatment - - - -	Closed septic tanks and single contact filtration followed by land treatment (Exeter Septic Tank Syndicate).
3. Population draining to works during observations	5,000 (estimated average).
4. Water supply in gallons per head and whence obtained	20 gallons, obtained from deep wells in the chalk—a hard water.
5. Average dry-weather flow of sewage treated by contact beds per 24 hours	150,000 gallons
6. Gallons of sewage per head per day - -	30.
7. Number of W.C.s - - - - -	About 1,100.
8. Character of the sewage - - - -	A domestic sewage, containing some brewery refuse.
9. Sewerage system - - - - -	Partially separate.
10. Period of observations at Andover - -	February, 1903 to August, 1905.
11. Age of primary beds - - - -	About $1\frac{1}{2}$ years; they were started in August, 1901.
12. Amount of storm-water treated on filters during observations	About twice the dry-weather flow is treated; but it depends largely upon the rate at which the pumps are working and the time at which the rainfall occurs.
13. Total capacity of tanks in gallons - -	Approximately 120,800.
14. Total area of filters in yards super - -	977·7.
15. Total cubic content of filter in yards cube	1,300.
16. Nature of filtering medium - - -	Locomotive clinkers, $\frac{1}{2}$-in., free from dust.
17. Gallons of settled sewage treated per yard super per 24 hours (all filters included).	153.
18. Gallons of settled sewage treated per yard cube per 24 hours	115.
19. The final effluent is discharged into - -	The River Anton; but very little reaches it.

FLOW OF SEWAGE.

Owing to the admittance of back-roof water and back-yard water to the sewers, and also to the fact that a quantity of ground water finds its way into the sewerage system in wet weather, the flow of sewage is subject to considerable increases in times of wet weather. There are no storm overflows on the system above the pumping station, and the whole of the storm water therefore reaches the receiving tank there. The bulk of it is sent up to the works, but a fair quantity passes over the overflow situated at the side of the receiving chamber, and thence direct to the river. We have not been able to form any estimate of the amount discharged in this way, but as the overflow (whose working depends upon that of the pumps) was allowed to come into operation only about 68 times during a period of 21 months (February, 1903, to October, 1904), it may be reasonably conjectured that the quantity is not very large.

A second storm-overflow is placed between the tanks and the filters; this is set so as to come into operation when the flow exceeds the maximum flow of 220,000 gallons per day, but, being dependent upon the working of the filters, it is possible for it to act at almost any state of the flow. Towards the end of 1904 the filters became rather clogged, and, owing to the slow rate at which they have filled since then, the flow of sewage into the tank has often exceeded the outflow of tank liquor from it; in consequence of this some tank liquor has been discharged unfiltered on to the land almost every day for some months.

The flow of sewage was measured by means of an automatic recorder throughout a period of six days, in August, 1905. As the weather during this period was dry, and as the preceding weather had been dry also, the estimate of dry-weather flow obtained may be taken to be approximately correct. The average flow per day during the six days was approximately 150,000 gallons, and this has therefore been taken as the dry-weather flow.

The highest flow, 173,000 gallons, occurred on the Saturday, when the swimming bath was emptied, and the lowest, 120,000 gallons, on the Sunday.

If the increase of flow which takes place on the emptying of the swimming bath is excepted, the flow of sewage is of a fairly even character, and may be said to fall gradually from a fairly steady flow at the rate of about 220,000 gallons per 24 hours, which continues from 9 a.m. to 6 p.m., to another steady flow of about 65,000 gallons per 24 hours during the early hours of the morning. In wet weather the variations are large.

It will be understood that the above remarks upon the variations in the flow apply to the sewage as it enters the receiving tank; owing to the pumping, all natural variations in the flow disappear after it has once entered the tank.

Subsoil Water.—Allowing for leakage from defective taps, the high rate of flow at night of something like 65,000 gallons per 24 hours (three-eighths of the total flow), occurring as it did during dry weather, is evidence of the fact that a large quantity of ground water gains access to the sewers.

Diagram B gives some typical illustrations of the sewage flow at Andover.

Crude Sewage.—Seven samples were examined chemically, six of them, Nos. 739, 742, 747, 810, 813 and 814 being sets of hourly samples extending over 24 hours each. These were drawn in two separate series of three sets each, at the end of October, 1904, and in the middle of August, 1905, respectively, the weather being dry in both cases, excepting that 0·03 inch of rain fell on the day before the first sample (No. 739) was taken. The three samples of the first series were of almost exactly the same strength, while the three of the second series also agreed well among themselves, though they were distinctly weaker than the first. The reason for drawing the second series was that in the first the suspended solids seemed small in quantity, relatively to the other figures of analysis, and it was thought advisable that this should be verified.

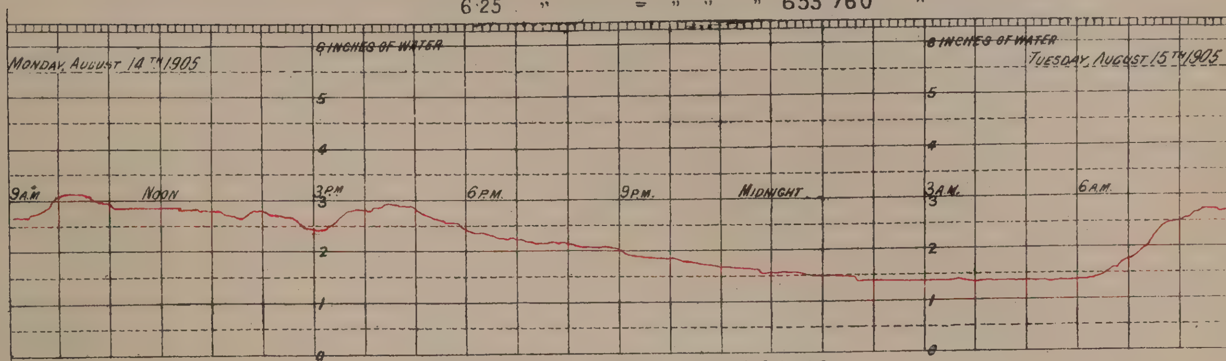
Diagram B.

Diagrams showing flow of Sewage at Andover as falling over a Weir 12" wide.

Note:- Over a Weir 12" wide

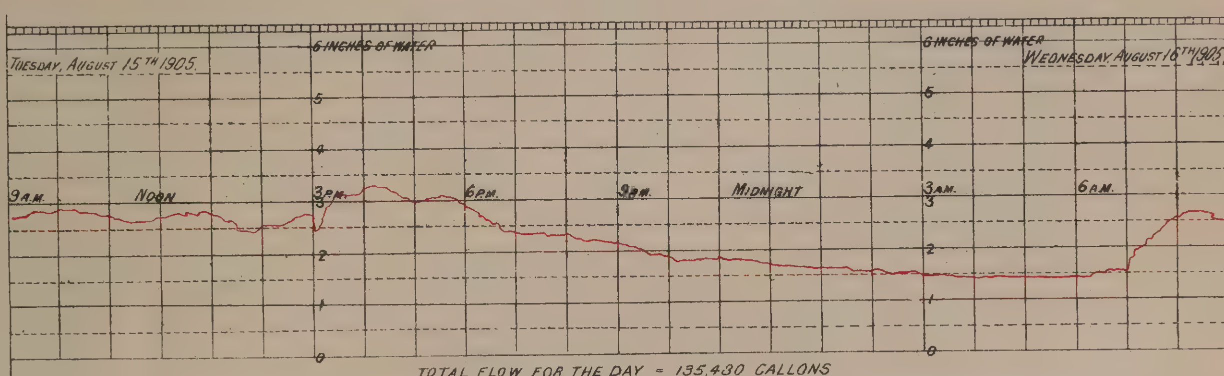
1·25 inches	= a rate of	59,040	gallons per 24 hours.
1·50 "	= " " "	76,464	" " " "
2·0 "	= " " "	118,080	" " " "
2·5 "	= " " "	164,160	" " " "
3·0 "	= " " "	216,000	" " " "
6·25 "	= " " "	653,760	" " " "

DAY.
ALL NIL.



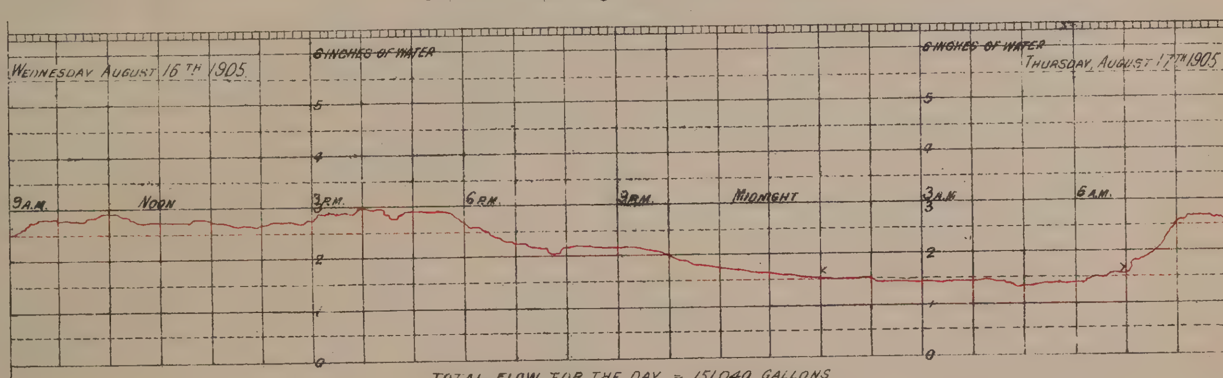
TOTAL FLOW FOR THE DAY = 153,540 GALLONS

DAY.
ALL NIL.



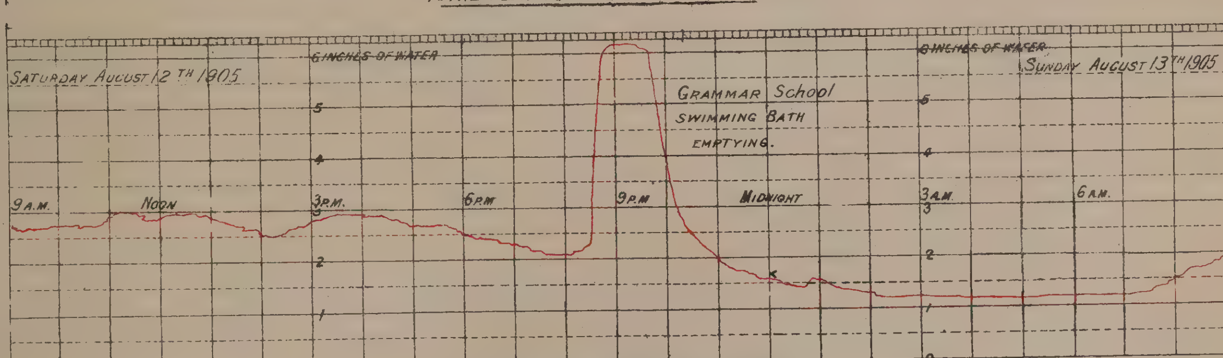
TOTAL FLOW FOR THE DAY = 135,430 GALLONS

DAY.
LL NIL.



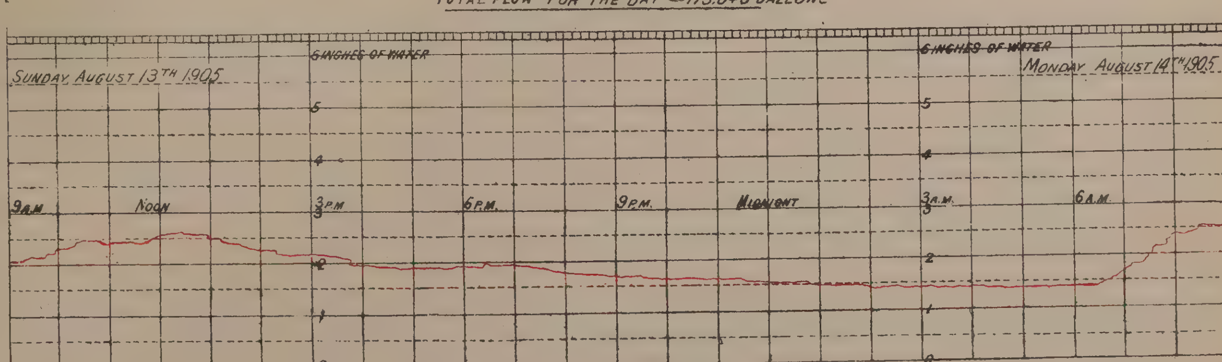
TOTAL FLOW FOR THE DAY = 151,040 GALLONS

DAY.
L NIL.



TOTAL FLOW FOR THE DAY = 173,040 GALLONS

DAY.
LL NIL.



TOTAL FLOW FOR THE DAY = 120,340 GALLONS.

Weller & Graham, Ltd. Litho London.

The above six samples gave the following results :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(4·74 to 7·83 (?)*)	6·19	(6)
Albuminoid Nitrogen	(0·76 to 1·25)	1·02	(6)
Total Organic Nitrogen	(1·49 to 2·86)	2·09	(5)
Total Nitrogen	(6·57 to 9·37)	8·06	(6)
"Oxygen absorbed" *at once*, at 27°C. (80°F.)	(2·37 to 3·15)	2·72	(6)
" " *in 4 hours* " "	(8·98 to 10·33)	9·77	(6)
Dissolved Oxygen taken up in 24 hours at about 18°C	(18·28 to 20·17)	19·17	(3)
Chlorine	(8·10 to 21·66)	13·97	(6)
Solids in Suspension	(13·4 to 18·3)	15·80	(6)
Solids by Centrifuge (vols.)	(64·0 to 143·0)	108·0	(6)
Ratio of Solids in Suspension to Centrifuge Solids	(1 : 4·2 to 1 : 8·9)	1 : 6·9	(6)

All the above samples had a strong and more or less offensive (brewery ?) smell. The Andover sewage is thus one of about average strength organically, but it contains relatively few suspended solids; in the first series these averaged 16·5 and in the second 15·1 parts per 100,000, those of the second series being much the more flocculent. No doubt, however, the brewery refuse present in it makes it more difficult to treat than a purely domestic sewage, shewing similar figures of analysis. The chlorine figures, especially those of the first series, are curious:—9·10, 21·66. 15·30; 8·10, 17·84, and 9·84. When read along with the other figures, they illustrate the danger of relying on chlorine alone as the measure of the strength of a sewage. The high chlorine content in the Andover sewage is due to the bacon-curing industry carried on in the town.

The one chance sample of sewage examined, No. 555 (drawn in June, 1903, after heavy rain for a few days previous), was stronger than the average of the hourly samples, both as regards total nitrogen (8·30 parts) and "oxygen absorbed" (14·06), but the centrifuge figure was lower (46·0); the sewage was at the moment abnormal, owing to the cleaning out of the pump well.

Bacteriological Notes.—The bacteriological results are shewn in the accompanying table. All samples yielded positive results with 1/100,000 c.c. (100,000 per c.c.) with the B. coli, neutral red broth and bile-salt glucose peptone tests. The B. enteritidis sporogenes test yielded positive results with 1/100 c.c. (100 per c.c.).

Description of Sample.	B. coli test.	N.R. = Neutral red broth test. In. = Indol test. L.P.M. = Lactose peptone milk test. B.S = Bile-salt glucose peptone test.	B. Enteritidis sporogenes test.	Remarks.
555. Andover crude sewage, 17/6/03	—	N.R. = 100,000	100 not 1,000	
739 Andover crude sewage, 1/11/04	100,000 (– indol) (– clot)	N.R. = 100,000 B.S. = 100,000	100 not 1,000	
747. Andover crude sewage, . 3/11/04	100,000 (– indol) (– clot)	N.R. = 100,000 B.S. = 100,000	100 not 1,000	
810. Andover crude sewage, 15/8/05	—	B.S. = 100,000 N.R. = 100,000	100 not 1,000	
813. Andover crude sewage, 16/8/05	—	B.S. = 100,000 N.R. = 100,000	100 not 1,000	
814. Andover crude sewage, 17/8/05	—	B.S. = 100,000 N.R. = 100,000	100 not 1,000	

* Probably a little too high.

SCREENS AND GRIT CHAMBERS.

Before flowing into the receiving chamber at the pumping-station, the sewage passes two screens, one having a half-inch and the other a quarter-inch mesh. The screenings from these are given away to farmers.

The receiving chamber at the pumping-station is cleaned out about once a week, and the two pump wells situated at the side of it about once a month. The matter taken from these, which consists very largely of grit, is put upon the land at the sewage works or given to farmers. This gritty matter amounts to about 1 cube yard a month from the pump wells, and about 3 cube yards a month from the receiving chamber.

At the top of the rising main, the sewage flows into a receiving channel 3 feet by 3 feet, and 3 feet deep, from which it passes into each tank through two inlets. This channel was originally open, but, on account of the nuisance to which it gave rise, it was found necessary to completely cover it. It is never cleaned out.

SEPTIC TANKS.

Number.—2. Size of each: 80 feet by 16 feet 8 inches.

Depth of water.—6 feet deep at low water and 8 feet 6 inches deep at high water.

(Note:—An automatic valve situated in the outlet channel from the tanks regulates the outflow of septic tank liquor. In consequence of this, the level of liquid in the tanks varies at different times.)

Capacity of each tank (mean water level).—Approximately 60,400 gallons.

Total capacity (mean water level).—Approximately 120,800 gallons.

Storage between high and low water levels.—41,666 gallons.

Construction.—Both tanks are constructed of cement and concrete throughout, and are covered with a concrete arch over which a layer of soil is spread. The sewage enters in each case from two inlets placed above the water level, and is drawn off below the surface level by means of a slotted pipe laid across the breadth of the tank. The tanks contain no submerged walls.

Flow through.—Assuming the flow through the tanks to be a continuous one, the dry-weather flow of 150,000 gallons per 24 hours would give a flow through at the mean water level of once in 19·3 hours, at the rate of ·83 of an inch per minute. At the maximum flow of 220,000 gallons per 24 hours, the flow through would be once in 13·1 hours, at the rate of 1·22 inches per minute.

Working.—In consequence of the pumping of the sewage before it enters the tanks and the siphonic regulation of the outflow of tank liquor, the working of the septic tanks is somewhat unusual. The period during which the sewage is pumped depends, of course, on the amount of sewage arriving at the receiving chamber, but, as a general rule, the pumps are at rest between about 5 p.m. and 7 a.m. Excepting when the water level in the tanks remains sufficiently high to actuate the automatic gear, by means of which the filters are filled and emptied, the liquid in the tanks is stagnant between these hours. In the daytime also, as has been previously explained, the valve which regulates the outflow of tank liquor causes the water level in the tanks to rise and fall. The tanks are used in parallel.

Sludging.—Previous to the commencement of the observations (that is to say, from August, 1901, to February, 1903), no sludge was removed from the septic tanks, and this also held good until February, 1904—a further period of 12 months. During the greater part of this last period of twelve months, a large quantity of suspended matter had been issuing in the tank liquor, and by the end of it the surfaces of the filters had become considerably clogged. In February, 1904, therefore, the sludge valves situated at the outlet end of the tanks were opened, and about 6,800 gallons of semi-liquid sludge were allowed to run into a channel cut in the ground a short distance from the tank. From this time some sludge was removed in the same way about once a month, the total quantity removed up to the end of July, 1904, *i.e.*, after three years' working, being estimated by the Borough Surveyor at approximately 130,000 gallons. The operation is an easy one, and can be quickly carried out by one man, but considerable smell arises from the channels until the sludge is dry.

Notwithstanding this periodical removal of sludge, a large quantity of suspended matter still continues to come out in the tank liquor (August, 1905), and for this reason, although we have not been able to make an estimate of the amount of sludge in the tanks, we think it is to be inferred that either the removal has not kept pace with the

accumulation, or, as is more probably the case, that the sludge valves, being situated at the outlet end, remove sludge only locally and exercise little effect upon the accumulations in the other parts of the tanks.

Septic Tank Liquor.—Thirteen samples were examined chemically, viz., three sets of hourly and ten chance samples. The hourly sets, Nos. 740, 743 and 746, were drawn at the same time as the hourly sets of sewage of Series 1, *i.e.*, at the end of October, 1904, and like the latter they were very uniform in composition. They gave the following figures on analysis :—

———	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(7·20 to 7·59)	7·44	(3)
Albuminoid Nitrogen	(0·88 to 1·04)	0·98	(3)
Total Organic Nitrogen	(1·56 to 1·88)	1·75	(3)
Total Nitrogen	(9·08 to 9·33)	9·52	(3)
"Oxygen absorbed" *at once* at 27°C. (80°F.)	(2·02 to 2·20)	2·07	(3)
,, ,, *in* 4 *hours* ,, ,,	(7·15 to 7·82)	7·53	(3)
Chlorine	(10·34 to 17·14)	13·83	(3)
Solids in Suspension	(9·90 to 12·50)	11·10	(3)
Solids by Centrifuge (vols.)	(51·0 to 54·0)	53·0	(3)
Ratio of Solids in Suspension to Centrifuge Solids	1 : 4·3 to 1 : 5·2	1 : 4·8	(3)

Judged by the figures for total nitrogen, the hourly sets of sewage of Series 1 and of septic tank liquor are fairly comparable with one another; but if we refer to the respective chlorine figures :—

Sewage	9·10	21·66	15·30
Septic Tank Liquor	10·34	17·14	14·00

it would appear that the flow through the tank must at the time have been uneven and the stay of liquid in the tank rather short. The average figure for suspended solids (which were fine, black and rather flocculent) in these hourly samples of septic tank liquor was 11 parts per 100,000; hence, the suspended solids of the sewage had not been much reduced in quantity or rendered much more dense by the tank treatment. The samples of septic tank liquor had of course a strong smell. At the time they were drawn the tank had been in use for over three years, but, as already explained, some sludge had been removed, at intervals, from February, 1904.

Compared with the hourly sets of sewage samples of Series 1, we get the following reduction in figures :—

Total Nitrogen	0 per cent.
Albuminoid Nitrogen	17 ,,
Total Organic Nitrogen	21 ,,
"Oxygen absorbed" *at once*	31 ,,
,, ,, *in* 4 *hours*	25 ,,
Solids in Suspension	33 ,,
Solids by Centrifuge (vols.)	38 ,,

The ten chance samples of septic tank liquor examined, Nos. 3094A, 486, 556, 667 678, 785, 789, 808, 811 and 815, were drawn—the first seven in the spring and early summer of the years 1903, 1904 and 1905, and the last three in August, 1905, for the most part in dry weather. They gave the following figures on analysis :—

———	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(4·74 to 6·72)	5·50	(9)
Albuminoid Nitrogen	(0·60 to 0·97)	0·76	(9)
Total Organic Nitrogen	(0·95 to 2·98)	1·51	(6)
Total Nitrogen	(5·57 to 9·70)	7·03	(7)
"Oxygen absorbed" *at once* at 27°C. (80°F.)	(1·44 to 2·82)	2·20	(10)
,, ,, *in* 4 *hours* ,, ,,	(5·65 to 10·94)	8·31	(10)
Dissolved Oxygen taken up in 24 hours at about 18° C.	(6·90 to 13·60)	9·55	(4)
Chlorine	(6·70 to 20·90)	11·43	(8)
Solids in Suspension	(6·60 to 19·20)	14·0	(9)
Solids by Centrifuge (vols.)	(26·0 to 112·0)	75·0	(9)
Ratio of Solids in Suspension to Centrifuge Solids	(1 : 2·7 to 1 : 6·7)	1 : 4·7	(8)

As was to be expected, the chance samples of tank liquor varied much more in composition than the hourly samples, but, excepting in the case of the chlorine and suspended solids, the variations were not excessive. Taken all over, the chance samples were weaker in nitrogenous matter than the hourly samples, but rather stronger as regards the figures for "oxygen absorbed" and for suspended solids. It may be observed that the analysis of samples Nos. 667 and 678, which were drawn in March and May, 1904, showed that the suspended solids in the tank liquor were sensibly diminished after the first removal of sludge. The greater quantities of suspended solids in the five last samples, however (Nos. 785 and 789, drawn in February and March, 1905, and Nos. 808, 811 and 815, drawn in August, 1905), and also in the hourly sets of samples (drawn in November, 1904), indicate that the removal of sludge from the tank has not kept pace with its accumulation.

As compared with the six sets of hourly samples of sewage. these chance samples of septic tank liquor show the following reduction in figures :—

Total Nitrogen - - - - - - - -	13 per cent.
Albuminoid Nitrogen - - - - - -	25 „
Total Organic Nitrogen - - - - - -	25 „
"Oxygen absorbed" *at once* - - - - -	19 „
„ „ *in 4 hours* - - - - -	15 „
Solids in Suspension - - - - - -	11 „
Solids by Centrifuge (vols.) - - - - -	30 „

Bacteriological Results.—The bacteriological results are shewn in the accompanying table. All eleven samples yielded positive results with 1/100,000 c.c. (100,000 per c.c.) with the B. coli, neutral red broth, indol, lactose peptone milk and bile-salt glucose peptone tests. The B. enteritidis sporogenes test usually gave a positive result with from 1/100 to 1/1,000 c.c. (100 to 1,000 per c.c.).

Description of Sample.	B. Coli test.	N.R. = Neutral red broth test. In. = Indol test. L.P.M. = Lactose peptone milk test. B.S. = Bile-salt glucose peptone test.	B. Enteritidis sporogenes test.	Remarks.
3094A. Andover tank liquor, 4/2/03	100,000 (+ indol) (+ clot)	N.R. = 100,000 In. = 100,000 L.P.M. = 100,000 B.S. = 100,000	1,000 not 10,000	"Gas" test +·001 c.c. (24 hrs. at 20° C.)
486. Andover tank liquor, 25/2/03	—	N.R. = 100,000	100 not 1,000	
556. Andover tank liquor, 17/6/03	—	N.R. = 100,000	100 not 1,000	
678. Andover tank liquor, 3/5/04	100,000 (+ indol) (+ clot)	N.R. = 100,000	100 not 1,000	
740. Andover tank liquor, 1/11/04	100,000 (+ indol) (+ clot)	N.R. = 100,000 B.S. = 100,000	1,000 not 10,000	
746. Andover tank liquor, 3/11/04	100,000 (+ indol) (+ clot)	N.R. = 100,000 B.S. = 100,000	100 not 1,000	
785. Andover tank liquor, 15/2/05	100,000 (+ indol) (+ clot)	N.R. = 100,000 B.S. = 100,000	1,000 not 10,000	
789. Andover tank liquor, 23/3/05	100,000 (– indol) (– clot)	N.R. = 100,000 B.S. = 100,000	10 not 100	
808. Andover tank liquor, 14/8/05	—	B.S. = 100,000 N.R. = 100,000	100 not 1,000	
811. Andover tank liquor, 16/8/05	—	B.S. = 100,000 N.R. = 100,000	100 not 1,000	
815. Andover tank liquor, 17/8/05	—	B.S. = 100,000 N.R. = 100,000	100 not 1,000	

FILTERS.

Number.—8. Size of each: 44 feet by 25 feet, approximately.

Area of each.—122·2 square yards.

Total Area.—977·7 square yards.

Depth of material.—4 feet.

Cubic content of each.—163 cube yards.

Total cubic content.—1,300 cube yards.

Material.—Locomotive furnace clinker, broken to pass a half-inch screen but freed from dust.

Construction.—Brick and cement throughout.

Distribution.—Six lines of 6-inch stoneware channels laid on the top of the filtering material, and fed by a main distributor ranging from 9 inches to 6 inches in diameter.

Underdraining.—The effluent is collected at the bottom of the filter by two lines of 2-inch agricultural pipes, laid on the filter floor. These discharge into a stoneware main collector, from 4 to 9 inches in diameter, which runs into a cast-iron discharge well containing the discharge valve.

Working.—The filters are divided into two groups of four filters each, three filters in each group constituting as a rule the working set, while the remaining two filters are being rested. The filling and emptying are effected automatically, by means of the automatic gear constructed by the Exeter Septic Tank Syndicate. As soon as a filter is filled, a small quantity of filtered effluent flows from the discharge valve into its actuating bucket. The fall of this bucket closes the admission valve to the filter and, on its rising again after the proper interval has elapsed, it opens the discharge valve and releases the contents of the filter. The discharge of a full filter brings about the emptying of the actuating bucket in the next filter, and the counterweight of this then comes into play, closing its discharge valve and opening its admission valve.

The gear of each set is arranged so that only one of its filters can be either filling or full at a given time, the other three filters being thus rested throughout the period of filling and standing full. The object of this is that the tank liquor may accumulate in the tank, and the filters fill more quickly in consequence; but, as will be seen from the paragraph upon the working of the septic tanks, the arrangement is by no means an advantage, for, to avoid an overflow of tank liquor on to the land, it would often be necessary to fill more than two filters at once.

The overflow pipes from all the filters in a group are connected into a continuous ring, by means of a four-way cock placed at every junction. By this means a filter may be cut out of or brought into the working set, as desired.

The time required to fill a bed and the length of contact have varied considerably during the life of the beds, chiefly because of their loss of capacity. During the observations the beds have, on the average, been filled in about three-quarters of an hour and have been given a contact of about one hour. Towards the end of the observations, owing to the clogged condition of the beds, and the more frequent filling of them which thus became necessary, the contact was usually not more than three-quarters of an hour. The average number of fillings given to each of the beds per day during these observations has been 1·4, and has varied from one filling at the beginning to three fillings at the end.

Age of beds.—The beds were first started in August, 1901.

Capacity.—The original empty tank capacity of all the filters together was 220,000 gallons. Assuming that the filtering material, when put into the bed, occupied one half of the bed space, the original total water capacity would be 110,000 gallons.

At the commencement of the observations, in February, 1903, the beds appeared to be in fairly good condition, but soon after they began to show signs of clogging, and from this time onwards constant attention and raking were necessary. On November 1st, 1904, the capacities of all the beds were gauged, and the total filter capacity was found to be approximately 30,400 gallons, *i.e.*, 13·8 per cent. of the original empty tank capacity or 27·6 per cent. of the original water capacity. Two causes seem to have brought about this serious loss, *i.e.* (1) the amount of suspended matter in the tank liquor, and (2) the degradation in the filtering material, this being so marked as to cause the surfaces of the beds to sink between three and six inches below their original level.

Amount of Sewage treated upon the Filters.—On the basis of a dry weather flow of 150,000 gallons per day, the amount of sewage treated by the Andover filters is as follows:—

Per square yard per 24 hours - - - -	153 gallons.
Per cube yard per 24 hours - - - -	115 gallons.

Effluents.—Three sets of hourly samples and twelve chance samples of effluent were examined chemically, besides one additional sample which had passed over land. The three sets of hourly samples, Nos. 741, 744 and 745, were drawn at the same time as the hourly samples of sewage (Series 1) and septic tank liquor, and they consisted respectively of 28, 27 and 26 discharges, *i.e.* of all the discharges from the whole of the filter beds for the day; these were always taken at mid-flow.

The following figures were obtained on analysis :—

———	*Parts per* 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - - - -	(4·69 to 5·02)	4·82	(3)
Albuminoid Nitrogen - - - - - - -	(0·54* to 0·63)	0·60	(3)
Total Organic Nitrogen - - - - - - -	(0·72 to 1·37)	1·05	(3)
Oxidized Nitrogen - - - - - - - -	(0·0 to 0·06)	0.0	(3)
Total Nitrogen - - - - - - - - -	(5·52 to 6·08)	5·89	(3)
"Oxygen absorbed" *at once* at 27°C. (80°F.) - - -	(0·95 to 1·19)	1·09	(3)
" " *in 4 hours* " " - - - - -	(3·85 to 4·64)	4·26	(3)
Dissolved Oxygen taken up in 24 hours at about 18°C.	- (2·09 by No. 741)		
Chlorine - - - - - - - - - -	(10·72 to 14·82)	13·10	(3)
Incubator test (Scudder) - - - - - - - - - -			
Incubator test (by smell) - - - - - - - - - -		3 failed	(3)
Smell when drawn - - - - - - - - - - -		3 sewage	(3)
Smell when analysed - - - - - - - - - - -		3 sewage	(3)
Solids in Suspension - - - - - - - -	(9·60 to 10·00)	9·80	(3)
Solids by Centrifuge (vols.) - - - - - -	(46·0 to 51·0)	49·0	(3)
Ratio of Solids in Suspension to Centrifuge Solids -	- (1 : 4·7 to 1 : 5·3)	1 : 5·0	(3)

* Possibly a little too high.

It will be seen that these samples were of very uniform composition. In appearance they were turbid and brown, with much suspended matter of a grey to brown colour. They all had a sewage smell when drawn and also when analysed, contained no nitrate, and failed to withstand incubation. The suspended matter amounted to 9·8 parts per 100,000. The effluents were thus of poor quality, but, as has been already stated, these were not final effluents.

As compared with the hourly samples of sewage (series 1) and of septic tank liquor, they show the following reduction in figures :—

Calculated on	Sewage.	Septic Tank Liquor.
Total Nitrogen	35 per cent.	39 per cent.
Ammoniacal Nitrogen	35 „	35 „
Albuminoid Nitrogen	49 „	39 „
Total Organic Nitrogen	53 „	40 „
"Oxygen absorbed" *at once*	63 „	48 „
„ „ *in 4 hours*	57 „	43 „
Solids in Suspension	41 „	12 „
Solids by Centrifuge	43 „	7 „

In addition to the hourly samples, twelve ordinary chance samples of contact bed effluent were examined chemically, viz. Nos. 3094B., 485, 557, 609, 668, 679, 3350, 786, 790, 809, 812 and 816, and also a further sample, No. 748, which was a sample of the effluent after land treatment, as finally discharged; the first nine samples were nearly all drawn in the spring and autumn months of 1903, 4 and 5, and the last three in August, 1905, two-thirds of them in dry weather. All of them were taken at mid-flow, excepting No. 609, which was drawn when the bed was three-fourths empty.

They gave the following figures on analysis :—

——	*Parts per* 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(2·14 to 5·19)	4·10	(9)
Albuminoid Nitrogen	(0·33 to 0·80)*	0·52	(8)
Total Organic Nitrogen	(0·71 to 1·16)	†0·85	(6)
Oxidized Nitrogen	(0·0 to 1·20)	‡0·43 ap.	(12)
Total Nitrogen	(4·34 to 6·20)	†5·45	(6)
"Oxygen absorbed" *at once* at 27°C. (80°F.)	(0·30 to 1·69)	1·08	(12)
„ „ *in 4 hours* „ „	(2·69 to 6·50)	4·02	(11)
Dissolved Oxygen taken up in 24 hours at about 18°C.	(0·59 to 4·72)	2·77 ap.	(7)
Incubator test (Scudder)		3 passed	(3)
Incubator test (by smell)		1 doubtful, 10 failed	(11)
Smell when drawn		1 good, 10 sewage	(11)
Smell when analysed		4 good, 4 doubtful, 4 sewage	(12)
Solids in Suspension	8·30 to 12·70)	9·60	(7)
Solids by Centrifuge (vols.)	(14·0 to 113·0)	52·0	(11)
Ratio of Solids in Suspension to Centrifuge Solids	(1 : 5·1 to 1 : 12·0)	1 : 7·4	(6)

* Possibly too high in No. 3094B. † Possibly a little too low. ‡ "Ap."=Approximately.

In appearance these effluents were for the most part turbid and brownish, and fully half of them contained large quantities of suspended solids (about 7 parts on the whole average, and about 11 parts in the last three samples drawn in August, 1905). Seven out of the twelve contained practically no nitrate when they came to be analysed, the oxidized nitrogen in the remaining five varying between 0·73 and 1·20 parts. Ten out of eleven were noted as having more or less of a sewage odour when they were drawn, and although four had a clean earthy smell and four a doubtful earthy smell on the day of analysis (having, no doubt, been drawing upon nitrate in the interval), only one—possibly—out of eleven withstood the incubator test.

These chance samples thus confirm what was said with regard to the hourly samples of effluent, viz., that one contact of the rather strong septic tank liquor at Andover, with one to three fillings per day, and at the rate of 115 gallons per cube yard per 24 hours, would be insufficient for proper purification, if this were regarded as a final process.

As compared with the six sets of hourly samples of sewage and the three sets of hourly samples of septic tank liquor, the chance samples of effluent show the following reduction in figures :—

Calculated on	Sewage.	Septic Tank Liquor.
Ammoniacal Nitrogen - - - - - -	34 per cent. reduction	45 per cent. reduction
Albuminoid Nitrogen - - - - - -	48 „ „	47 „ „
"Oxygen absorbed" *at once* - - - - -	60 „ „	48 „ „
„ „ *in* 4 *hours* - - - - -	59 „ „	47 „ „
Solids in Suspension - - - - -	*53 „ approx.	*33 „ approx.

*To get at the approximate reduction of the solids in suspension, these have been taken from the centrifuge figures at an average of 7·4 parts in all the twelve chance samples of effluent examined.

Samples Nos. 3550, 786 and 790, which have been included in the twelve samples of effluent just discussed, were examined both before and after filtration through paper, or before and after settlement, in order to judge of the extent to which the suspended solids took up dissolved oxygen and oxygen from permanganate, with the following results :—

——	No. 3550.		No. 786.			No. 790.	
	Original.	Filtered.	Original.	Settled over-night.	Filtered.	Original.	Settled 2 hours.
"Oxygen absorbed" *at once* -	0·86	0·47	1·17	0·88	0·58	1·45	1·48
„ „ *in* 4 *hours*	3·04	1·26	4·33	3·51	2·02	6·50	5·86
Dissolved Oxygen taken up in 24 hours - - - -	0·59	0·21	3·65	3·20	1·65	*1·89 +	*2·05 +
Incubator test (by smell) -	Failed	Passed	Failed	Failed	Doubtful	Failed	Failed
Solids in Suspension - -	8·40	—	8·30	—	—	9·20	6.10
Solids by Centrifuge (vols). -	46·0	—	—	—	—	47·0	29·0

* "1·89 +" and "2·05 +" indicate that the oxygen present was exhausted and that the effluents took up more than 1·89 and 2·05 parts of oxygen respectively.

In the case of the first of these effluents, No. 3550, the separation of the solids (by paper filtration) converted a very indifferent effluent into one of fair or good quality; in the case of No. 786, a bad effluent, the complete removal of the solids almost allowed of the liquid withstanding incubation (the records for the settled portion of this sample are inadequate); in the case of No. 790, also a bad effluent, the two hours' settlement only reduced the suspended solids from 9·2 to 6·1 parts per 100,000, with very little general improvement in the figures of analysis.

Again, in the settled portion of No. 786, the amount of dissolved oxygen taken up in 24 hours was 3·2 parts per 100,000, as against 5·1 parts taken up in five days, this confirming what has been found in many other instances, viz. :—that unless an effluent be very much diluted with pure water, it will take up oxygen at a greater rate during the first day than during the second, and so on.

Bacteriological Results.—The bacteriological results are shewn in the accompanying table. All the 14 samples of contact bed effluent yielded positive results with from ·0001 to ·00001 c.c. (10,000 to 100,000 per c.c.) with the B. coli, neutral red broth, indol, lactose peptone milk, and bile-salt glucose peptone tests. The majority of the samples contained from 10 to 1,000 (usually 100) spores of B. enteritidis sporogenes per c.c. Sample 748, derived from the land, contained 10,000 B. coli, but only 1 spore of B. enteritidis sporogenes per c.c.

Description of Sample.	B. Coli test.	N.R. = Neutral red broth test. In. = Indol test. L.P.M. = Lactose peptone milk test. B.S. = Bile-salt glucose peptone test.	B. Enteritidis sporogenes test.	Remarks.
3094B. Andover effluent, 4/2/03	100,000 (− indol) (− clot)	N.R. = 100,000 In. = 10,000 not 100,000 L.P.M. = 100,000 B-S. = 100,000	10 not 100	Number of microbes per c.c. = 6 million (gelatine at 20° C.). "Gas" test + ·01 c.c. (24 hrs. at 20° C.).
485. Andover effluent, 25/2/03	—	N.R. = 10,000 not 100,000	100 not 1,000	
557. Andover effluent, 17/6/03	—	N.R. = 100,000	100 not 1,000	
609. Andover effluent, 28/9/03	100,000 (− indol) (− clot)	N.R. = 100,000	1 not 10	
668. Andover effluent, 7/3/04	10,000 not 100,000 (− indol) (+ clot)	N.R. = 10,000 not 100,000	100 not 1,000	
679. Andover effluent, 3/5/04	100,000 (+ indol) (+ clot)	N.R. = 100,000	1,000 not 10,000	
3550. Andover effluent, 6/10/04	10,000 not 100,000 (+ indol) (+ clot)	N.R. = 100,000 B.S. = 10,000 not 100,000	100 not 1,000	
741. Andover effluent, 1/11/04	100,000 (+ indol) (+ clot)	N.R. = 100,000 B.S. = 100,000	100 not 1,000	
745. Andover effluent, 3/11/04	100,000 (− indol) (+ clot)	N.R. = 100,000 B.S. = 100,000	100 not 1,000	
786. Andover effluent, 15/2/05	100,000 (+ indol) (+ clot)	N.R. = 100,000 B.S. = 100,000	100 not 1,000	
790. Andover effluent, 23/3/05	10,000 not 100,000 (− indol) (− clot)	N.R. = 100,000 B.S. = 10,000 not 100,000	1,000 not 10,000	
748. *Andover effluent after land treatment,* 3/11/04	10,000 not 100,000 (+ indol) (+ clot)	N.R. = 100,000 B.S. = 10,000 not 100,000	1 not 10	
809. Andover effluent, 14/8/05	—	B.S. = 100,000 N.R. = 100,000	10 not 100	
812. Andover effluent, 16/8/05	—	B.S. = 100,000 N.R. = 100,000	10 not 100	
816. Andover effluent, 17/8/05	—	B.S. = 100,000 N.R. = 100,000	10 not 100	

Washing of the Contact Bed Material.—After the contact beds had been in operation for about 4 years the beds began to show such serious signs of clogging that the authorities decided to commence washing the whole of the material. This operation was begun in August, 1905.

It may be of interest to describe briefly the method and plant employed for washing. The plant was devised by the surveyor to the Council. It is inexpensive, works well, and appears to be well adapted to small installations where special washing machinery would be out of the question, owing to the initial outlay and maintenance charges.

The plant consists of an ordinary gravel screen, hinged at one end to a support, and placed in a wooden box filled with water to within about 12 inches of the top, so that the water nearly covers the material to be washed. The dirty clinker is filled into the screen and the water turned on, the material being shifted backwards and forwards by an iron rake, while the dirty water runs off by an overflow placed slightly above the screen level. When the material is washed, the contents of the screen are tilted by means of the hinge and a counterweight into a wheelbarrow, the water is turned off and the silt removed from the box. The screen is then replaced, and a fresh load of material put in.

Three men are kept constantly at work, one filling and wheeling, and the other two raking and emptying the box. The water supply is obtained from the town mains.

The cost of the plant was as follows :—

	£	s.	d.
Screen - - - - - - - -	1	10	0
Wooden box - - - - - - -	1	10	0
Iron piping for water supply - - - -	1	10	0
Timber planking, etc. - - - - -	1	10	0
Total - -	£6	0	0

The time occupied in washing and replacing the material of three beds was about 16 weeks, or an average of 5·3 weeks per bed.

The total cost for the 3 beds was :—

	£	s.	d.
Initial outlay on plant - - - - - -	6	0	0
Labour and cost of replacing rejected material	50	16	7
Total - -	£56	16	7

Each of the 8 contact beds contains 163 cubic yards of material, so that the cost of washing and replacing the material of the above three beds, including plant, was about 2s. 4d. per cube yard.

LAND.

The land lies on the side of the valley of the river Anton. It has an area of approximately 8 acres, all of which is available, and consists of a surface soil of stiff loam with gravel in parts, the whole overlying chalk. It is not underdrained.

The filter effluent (and, when the overflow is in operation, the septic tank liquor also) is distributed over the land by means of small grips cut in the soil. In the lower part, where the slope just touches the flat land lying at the side of the river, but some little distance from it, the soil is usually rather moist, and the oozings from this find their way into an intercepting ditch, and are occasionally carried in this way into a small backwater of the river. As a rule, however, there is no water flowing along this channel, and the liquid entirely disappears, either laterally by slow percolation, or, as is perhaps more probable, directly downwards into the chalk.

One sample (No. 748) of land effluent, finding its way to the river along the intercepting ditch, was taken. For a week prior to the date on which this was drawn, the effluents from the contact beds had been passed continually over about 1½ acres of rye grass. The above sample was almost clear and practically free from solids, and although it contained little or no nitrate, it took up hardly any dissolved oxygen in 24 hours, and it also withstood the incubator test. It is more or less comparable with the hourly sets of effluent samples which were taken about the same time; no further argument, therefore, is required to show the beneficial effect produced by this subsequent land treatment of the contact bed effluent.

SUMMARY.

The Andover sewage is a domestic one of about average strength organically, but with comparatively few suspended solids in it; it contains brewery refuse, but not in large proportion.

The settlement effected by the tanks was not good at the time the first series of hourly samples were taken, as much as 11 parts of suspended solids passing away in the septic tank liquor. At this date—November, 1904—the tanks had been in use for over three years, but some sludge had been removed from them at intervals of about a month from February, 1904, *i.e.*, during the nine months which preceded the sampling. Nor did the settlement in the tanks appear to have improved by the time the second series of hourly samples of sewage were drawn—in August, 1905.

The frequent periodical removal of small quantities of sludge from septic tanks is a comparatively new procedure. Although we are unable to offer an opinion as to the actual amount of sludge in the tanks at Andover, the high figures for suspended solids given by the samples of tank liquor examined would indicate that the above method of withdrawing sludge, from the outlet end of the tank only, had not been very effective in this case. More satisfactory results would no doubt have been obtained if additional valves or other means had been provided at various parts of the tank for the purpose.

If the sludge in a shallow rectangular tank is of a very liquid character, its partial removal from one point will result in the remainder spreading itself more or less evenly over the floor of the tank. But when a thick, semi-solid, layer is allowed to accumulate on the bottom—and this has usually been the case hitherto—equalization of the residue is much less likely to take place.

At one time there was a good deal of nuisance at the Andover works from the feed channels to the septic tanks being open, but this was remedied by closing these in, and there is now no nuisance from the ordinary working of the tanks. Some nuisance does arise, however, from the sludging; if the weather is dry at the time, this only persists for a day or so, but for longer if the weather is broken.

Treatment by septic tank and single contact of sewage of the strength of that at Andover is insufficient to produce an effluent that would pass a reasonable standard of purity, though this is in part due to the suspended solids that the effluent contains. The process, however, is supplemented by treatment on land at Andover.

At the beginning of the observations, in February, 1903, the filter beds received only a little more than one filling per day, but they lost capacity so rapidly that they were being filled three times a day in March, 1905, *i.e.* within a period of two years. In August, 1905, steps were being taken to have the filtering material washed. The beds have lasted, practically speaking, for four years. The shortness of their "life" has been due (1) to the large quantity of suspended matter in the tank liquor (about 10 to 11 parts per 100,000, during the above two years), and (2) to the degradation of the fine locomotive clinker used as the filtering material. By September, 1904, the level of the beds had sunk from 3 to 6 inches, and, when they were opened in the summer of 1905, the material was found to be much consolidated.

The automatic gear for filling and emptying the filter beds at Andover has worked well and has required only occasional supervision. Without it, the whole time of two men would probably have been required on the works, whereas, with it, a part of one man's labour is sufficient. Further, it ensures regularity of working, and, under normal conditions, allows of the beds being satisfactorily drained when they are run off. On the other hand it has the distinct disadvantages of not being able to adapt itself to a varying flow of sewage and of permitting only one bed in each set to be filled at one time.

We are indebted to Mr. R. W. Knapp, the Borough Surveyor, for much help during our observations.

CALVERLEY SEWAGE WORKS.

1.	Situation of works	About a mile from the centre of the population.
2.	Method of Treatment	Chemical precipitation, continuous flow subsidence, and single contact filtration:—
3.	Population draining to works during observations	2,300 (estimated average).
4.	Water supply in gallons per head and whence obtained	10, from the Bradford Corporation water supply—a soft moorland water.
5.	Number of W.C's	75.
6.	Sewerage system	Combined.
7.	Average dry weather flow in gallons per 24 hours	12,000.
8.	Gallons of sewage per head per day	5·2.
9.	Character of the sewage	Mainly a strong slop water sewage.
10.	Period of observations	July, 1902 to July, 1904.
11.	Age of beds	7 years.
12.	Amount of storm water treated	Up to about 30 times the dry weather flow.
13.	Total capacity of tanks in gallons	23,500.
14.	Total area of contact beds in yards super	391.
15.	Total cubic content of contact beds in yards cube	391.
16.	Nature of filtering medium	Clinker, $\frac{1}{4}$ inch to 2 inch gauge.
17.	Gallons of precipitation liquor treated per yard super per 24 hours (all filters included)	30·6.
18.	Gallons of precipitation liquor treated per yard cube per 24 hours (all filters included)	30·6.
19.	The final effluent is discharged into	The River Aire.

FLOW OF SEWAGE.

The greater portion of the rain falling upon the drainage areaenters the sewers and flows rapidly down the steep sewer towards the works. A storm overflow, however, situated near the middle of this gradient, diverts a portion of the very heavy wet weather flows direct to the Leeds and Liverpool Canal. We understand that this overflow is set so as to come into operation when the volume reaches six times an estimated dry weather flow of 30,000 gallons per 24 hours.* Another small storm-overflow at the works diverts a further quantity of storm water into the main effluent channel, which discharges into the river Aire.

The highest rate of flow in wet weather, recorded by a gauge placed between the two overflows, has been about 500,000 gallons per 24 hours. This flow, or a flow somewhere near it, has been recorded during sharp showers of rain on a number of occasions; each time it has occurred the flow has remained practically constant somewhat near this point for a short time, the inference therefore being that this flow is the maximum brought to the works, and that the main storm overflow diverts anything in excess of it. The storm overflow at the works comes into operation in the ordinary way when the flow reaches a rate of about 140,000 gallons per 24 hours; but because it is situated at the side of the inlet channel and therefore allows large flows to pass it while it is working, and also because the rate of flow at which it comes into operation may be and is altered by the size of the block of precipitant laid in the channel, it is impossible to make a definite statement as to the volume of liquid going over it. Probably, as a rough estimate, of the maximum 500,000 gallons brought to the works, about a quarter might flow over the small works overflow; on this basis the tanks and filters do at times deal with flows of sewage up to roughly 31 times the dry weather flow.

The variations in the flow at Calverley during showery weather are extraordinary, no doubt, because of the rapid gradient (one in ten) of the main sewer. On quite a number of occasions an increase in the rate of flow, in the proportion of about 25 to 1 within ten minutes, has been recorded; but in regard to this it is necessary to point out that, unless the heavy rain continues for some time, the diminution in flow at the end of the shower is almost as rapid. The greatest volume of sewage actually arriving at the works on any one day during the three gaugings was about 55,000 gallons.

Three separate measurements of the sewage flow have been made at Calverley; one in July, 1902, another in March, 1903, and the third in July, 1904. The gauging la-ted for seven days on each occasion. The measurements made in July, 1902, gave the dry weather flow as approximately 12,000 gallons per day, and those in July, 1904, also gave it as about 12,000 gallons. The dry weather flow may therefore be taken as 12,000 gallons per day. At such a time the flow is of an even character, the variations in volume being in the proportion of three in the daytime to one at night.

The highest flow during the day in dry weather was at the rate of 21,000 gallons per 24 hours, and the lowest (which appeared to be a steady flow of subsoil water and water leaking from taps) at the rate of about 5,250 gallons per 24 hours. The highest day flow in dry weather occurs on the Monday and the Tuesday of the week, but there is in reality very little difference between the flows on the different days.

It will be noticed that the recorded flow of 12,000 gallons per day in dry weather is about half what the estimated flow should be, on the basis of the water supply per head of the population. We are unable to account for this.

Subsoil Water.—From the almost constant night flow at the rate of about 5,250 gallons per 24 hours, it is fair to suppose that a considerable quantity of ground water, in addition to leakage from taps, finds its way into the sewers in dry weather.

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* As will be seen below, this estimate of 30,000 gallons is much too high.

In wet weather, or in dry weather while the ground is still wet, it is evident that a very large quantity of subsoil water comes to the works; in this respect the Calverley flow measurements are instructive.

Although the dry weather flow in perfectly dry weather is approximately 12,000 gallons, it is very much greater in dry weather which has been preceded by rain. Thus, in March, 1903, when such conditions prevailed, the flow on a perfectly dry day amounted to something like 50,000 gallons for the 24 hours.

On Diagram C. are given some illustrations of the sewage flow at Calverley.

Crude Sewage.—Hourly samples of crude sewage from Calverley were examined on two separate occasions, the reason for drawing the second series being that the first was to a great extent affected by rain. The second series will therefore be taken as typical of the dry-weather flow. It consisted of the usual three sets of samples, Nos. 3,479, 3,483 and 3,488, extending over 24 hours each, and drawn in July, 1904, in dry weather. The preceding week, up to Saturday, had been dry, and although on Saturday 0·20 inch of rain fell, and on Monday (the first day of sampling) 0·02 inch, this rainfall did not show on the charts. The following figures were obtained:—

Series 2.	Parts per 100,000.	Average.	Number of Estimations.	No. 3485. Weak Night Sewage.
Ammoniacal Nitrogen - - - - - -	(11·00 to 13·32)	11·82	(3)	4·79
Albuminoid Nitrogen - - - - - -	(1·71 to 1·89)	1·80	(3)	0·60
Total Organic Nitrogen - - - -	(2·05 to 3·53)	2·98	(3)	0·99
Oxidized Nitrogen - - - - - -		0·0	(3)	0·0
Total Nitrogen - - - - - - -	(14·35 to 15·37)	14·80	(3)	5·78
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(5·86 to 8·53)	7·42	(3)	1·48
,, ,, ,, ,, *in 4 hours*	(23·14 to 33·06)	29·55	(3)	6·00
Chlorine - - - - - - - - -	(14·50 to 16·10)	15·30	(3)	8·34
Solids in Suspension - - - - -	(13·10 to 41·40)	31·90	(3)	2·90
Solids by Centrifuge (vols.) - - - - -	(119·0 to 265·0)	193·0	(3)	24·0
Ratio of Solids in Suspension to Centrifuge Solids - - - - - - -	(1 : 6·3 to 1 : 9·1)	1 : 7·3	(3)	1 : 8·3

It requires but a glance at the foregoing figures to see that the Calverley dry-weather sewage is an exceedingly strong one in every respect, excepting as regards suspended solids, which in the above samples were in a very finely divided condition. All three sets of samples had a very sour sewage smell on the day of analysis. The sample of weak night sewage, No. 3485, drawn on July 6th, 1904, at 6.30 a.m., was unusually strong. It would appear to have been drawn too late to represent the weakest sewage of the 24 hours.

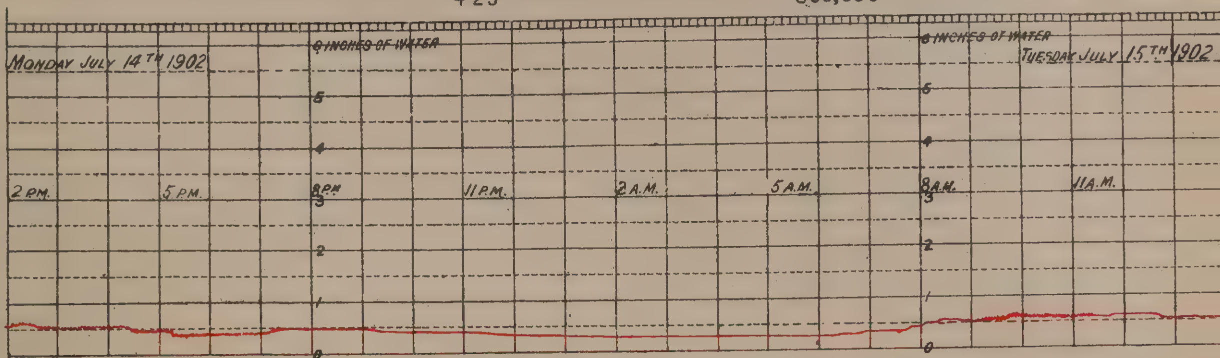
The results of the analysis of the first series of hourly samples, Nos. 3,000, 3,004, 3,008 and 3,010, drawn in July, 1902, may also be given, but it will be seen that these samples differ widely among themselves. The four sets of this series extended over a week, *i.e.*, over 48, 24, 48 and 48 hours respectively. The first two were much affected by rain, but the last two were drawn in dry weather. No. 3010 included the sewage of Monday, washing day. Alongside are given the figures of analysis of a sample of

Diagram C.

Diagrams showing flow of Sewage at Calverley as falling over a Weir 12" wide.

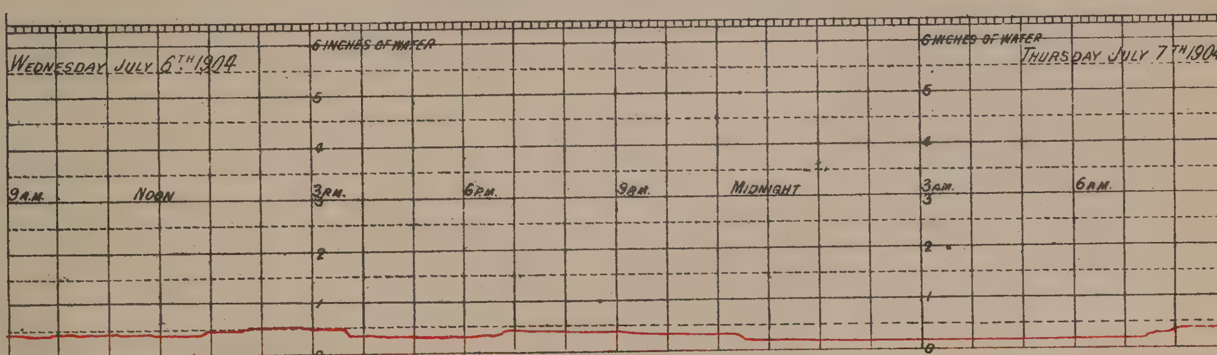
Note:- Over a Weir 12" wide	·25 of an inch	=	a rate of	5,210 gallons	per	24 hours.
	·50 " " "	=	" " "	14,830	"	" " "
	·75 " " "	=	" " "	27,360	"	" " "
	1·00 inch	=	" " "	41,760	"	" " "
	2·00 inches	=	" " "	118,080	"	" " "
	3·00 "	=	" " "	216,000	"	" " "
	4·25 "	=	" " "	360,000	"	" " "

RY DAY.
INFALL NIL.



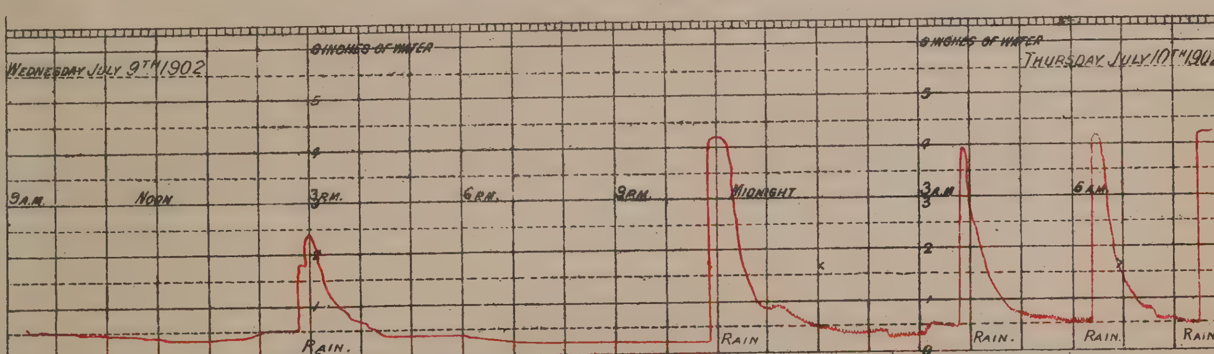
TOTAL FLOW FOR THE DAY = 13,605 GALLONS.

RY DAY.
NFALL NIL.



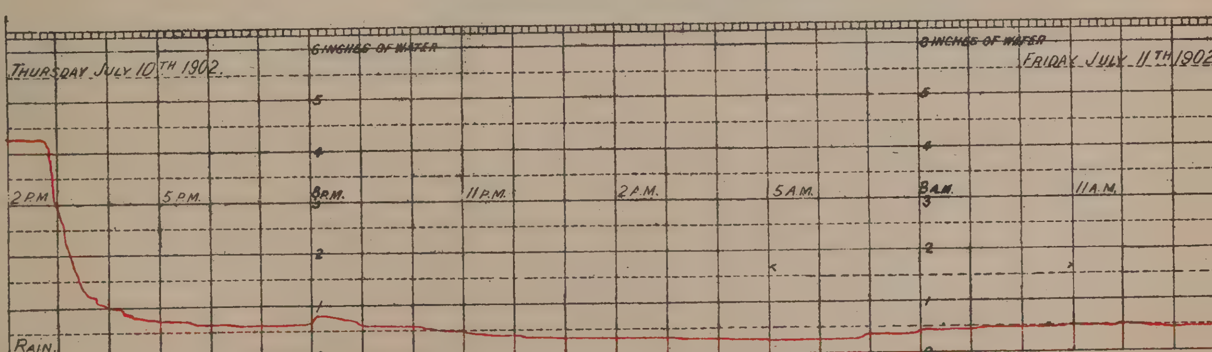
TOTAL FLOW FOR THE DAY = 10,907 GALLONS.

ET DAY.
L 0·46 INCH.
N 5 SHOWERS.)



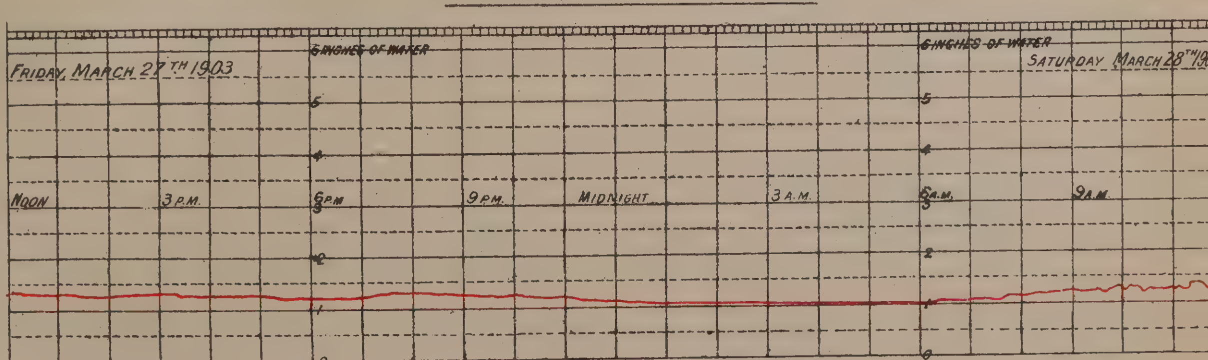
TOTAL FLOW FOR THE DAY = 43,700 GALLONS

RY DAY,
HE ABOVE WET DAY.
0·06 INCH.
IN FIRST HOUR.)



TOTAL FLOW FOR THE DAY = 31,485 GALLONS

WINTER) DAY,
WET WEATHER.
FALL NIL.



TOTAL FLOW FOR THE DAY = 55,560 GALLONS

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Weller & Graham. Ltd Litho. Londo

storm overflow discharge, No. 3,381, taken after the overflow had been working for 24 hours, although not much liquid was then passing over it. The following figures were obtained :—

Series 1.	Parts per 100,000.	Average.	Number of Estimations.	No. 3,381. Storm Overflow Discharge.
Ammoniacal Nitrogen - - - -	(5·12 approx. to 11·17)	8·32	(4)	1·50
Albuminoid Nitrogen - - - - - -	(0·89 to 2·61 ?)	1·50	(4)	0·51
Total Organic Nitrogen - - - -	(1·68 to 3·22)	2·33	(3)	
Oxidized Nitrogen - - - - - -		0·0	(4)	0·06
Total Nitrogen - - - - - -	(7·76 to 14·01)	10·73	(4)	
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(2·16 to 8·02)	4·15	(4)	1·20
" " " " *in 4 hours*	(10·53 to 23·58)	15·94	(4)	7·77
Chlorine - - - - - - - -	(6·82 to 15·70)	11·51	(4)	
Solids in suspension - - - - - -	(24·20 to 97·10)	49·50	(4)	13·0
Solids by Centrifuge (vols.) - - - -	(73·0 to 426·0)	232·0	(4)	101·0
Ratio of Solids in Suspension to Centrifuge Solids - - - - - - - -	(1 : 3·0 to 1 : 6·2)	1 : 4·5	(4)	1 : 7·8
"Cellulose" (by alkali, acid and ether) -	(2·92 to 8·96)	5·87	(3)	
Ratio of "Cellulose" to Solids in Suspension	(1 : 8·4 to 1 : 10·9)	1 : 9·5	(3)	
Incubator test (by smell) - - - -				Failed.

The two last sets of this series approximated in strength to the three sets of Series 2. Taking the figures all over, it is seen that the effect of rainfall at Calverley is very marked, and that the storm overflow at the works may continue to discharge a polluting liquid for long periods at a time.

Bacteriological Results.—The bacteriological results are shown in the accompanying table. All the samples of sewage yielded positive results with ·00001 c.c. (100,000 per c.c.) with the B. coli, neutral red broth, lactose peptone milk, indol and bile-salt glucose peptone tests. The B. enteritidis sporogenes test yielded results varying from 1 to 1,000 spores per cubic centimetre.

Description of Sample.	B. Coli test.	N. R.=Neutral red broth test. In=Indol test. L.P.M.=Lactose peptone milk test. B.S.=Bile-salt glucose peptone test.	B. Enteritidis Sporogenes test.	Remarks.
3000. Calverley Crude Sewage, 10/7/02.	—	L.P.M.=100,000 B.S.=100,000	100 not 1,000	
3004. Calverley Crude Sewage, 11/7/02.	—	—	10 not 100	
3010. Calverley Crude Sewage, 15/7/02.	100,000 (–indol) (+clot)	N.R.=100,000 In.=100,000 L.P.M.=100,000 B.S.=100,000	10 not 100	"gas" test +·0001 c.c. (24 hours at 20°C.)

Description of Sample.	B. Coli test.	N.R. = Neutral red broth test. In. = Indol test. L.P.M. = Lactose peptone milk test. B.S. = Bile-salt glucose peptone test.	B. Enteritidis Sporogenes test.	Remarks.
3381. Calverley *Storm Sewage*, 9/2/04.	100,000 (− indol) (+clot)	N.R. = 100,000	1 not 10	
3483. Calverley Crude Sewage, 6/7/04.	100,000 (+indol) (+clot)	N.R. = 100,000 In. = 100,000 L.P.M. = 100,000 B.S. = 100,000	1,000 not 10,000	
3485. Calverley Crude Sewage, 6/7/04.	100,000 (− indol) (+clot)	N.R. = 100,000 In. = 100,000 L.P.M. = 100,000 B.S. = 100,000	1 not 10	
3488. Calverley Crude Sewage, 7/7/04.	100,000 (− indol) (+clot)	N.R. = 100,000 In. = 100,000 L.P.M. = 100,000 B.S. = 100,000	100 not 1,000	

PRECIPITATION TANKS.

Number - - - - -	2.
Size of each - - -	50 feet by 12 feet.
Working depth - - - -	3 feet 2 inches.
Total capacity - - - -	23,500 gallons.
Construction - - - -	Rectangular tanks constructed of brick and cement, with a concrete bottom, and containing one submerged wall in each tank near the outlet end.

The Precipitant.—The precipitant used is alumino-ferric. It is put into the sewage channel in the form of blocks. The average amount used per week during the whole of the observations was about 210 lbs., equivalent to about 17·5 grains per gallon on the dry weather flow.

Working.—Having received the precipitant, the sewage is allowed to flow through the tanks, which are used in series. It issues from the second tank over a long sill, which is protected by a scum board.

Flow Through.—With the dry weather flow of 12,000 gallons, the flow through would be once in 47 hours, at the rate of ·21 inch per minute. During the time of a maximum flow of about 500,000 gallons per 24 hours, the flow through would be once in 1·1 hours, at the rate of 9·0 inches per minute.

Sludging.—The time at which it becomes necessary to clean out the precipitation tanks naturally depends upon the weather and the temperature. During the observations it averaged once a month for the first tank and about once in two months for the second tank.

The cleaning is done as follows :—After first diverting the whole flow of sewage into the other tank, the supernatant liquid in the tank to be cleaned out is drawn off by means of floating arms, and the sludge is then allowed to run through the sludge valve into the sludge tanks situated at the side of the precipitation tanks. A small portion of the sludge lying near the inlet of the first tank is sometimes too solid and gritty to flow through the sludge valve, and this has to be removed by hand ; but the bulk of it and also the whole of the sludge in the second tank is liquid enough to flow naturally.

There are three sludge tanks or lagoons; one constructed of brick and concrete and two by a simple excavation. The bottoms of these are covered with about twelve inches of ashes, and they are drained by means of agricultural pipes laid underneath the ashes. The drainings flow to the effluent channel.

The sludge from the lagoons, when sufficiently dry, is taken by a neighbouring farmer and used as a top dressing for grass land. He is allowed to take it free of charge.

Precipitation Liquor.—Seven sets of hourly samples and two chance samples of precipitation liquor were examined chemically. For the reasons given when dealing with the crude sewage, the second series of hourly samples, Nos. **3480**, **3484** and **3489**, drawn in July, 1904, must be taken as the typical series. They were, of course, drawn under the same conditions as the second series of hourly samples of crude sewage; but the length of stay in the precipitation tanks being 47 hours, they do not actually correspond with the latter, but represent approximately the sewage of two days before.

They gave the following figures on analysis :—

Series 2.	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(7·40 to 11·13)	9·64	(3)
Albuminoid Nitrogen	(1·01 to 1·18)	1·11	(3)
Total Organic Nitrogen	(1·59 to 2·47)	2·05	(3)
Total Nitrogen	(9·50 to 13·50)	11·66	(3)
"Oxygen absorbed" at 27°C. (80°F.) *at once*	(2·14 to 4·61)	3·51	(3)
,, ,, ,, ,, *in 4 hours*	(7·20 to 16·53)	11·94	(3)
Chlorine	(11·19 to 14·46)	12·49	(3)
Solids in Suspension	(8·80 to 17·80)	11·80	(3)
Solids by Centrifuge (vols.)	(40·0 to 52·0)	47·7	(3)
Ratio of Solids in Suspension to Centrifuge Solids	(1 : 5·8, 2·8 and 4·5)	1 : 4·4	(3)

These samples were very soapy and had a strong septic tank smell when drawn, and a very offensive smell when they came to be analysed. They still contained **12** parts per **100,000** of suspended solids, showing that the settlement in the precipitation tanks at Calverley is indifferent. In the second day's sample, No. **3484**, five-sixths of these suspended solids consisted of organic matter.

If the respective figures for ammoniacal nitrogen be taken as an index, it will be seen that these hourly samples of precipitation liquor correspond fairly well with the second series of hourly samples of crude sewage. Subject to this, comparing the two together, we get the following reduction figures :—

Calculated on :—	Reduction.
Albuminoid Nitrogen	38 per cent.
Total Organic Nitrogen	31 ,,
"Oxygen absorbed" *at once*	53 ,,
,, ,, *in 4 hours*	60 ,,
Solids in suspension	63 ,,
Solids by centrifuge (vols.)	75 ,,

The average figures for the hourly samples of Precipitation Liquor of Series **1**, Nos. **3001**, **3005**, **3009** and **3011**, may also be given here, though, for the reasons already stated, they cannot be taken as typical. It will be seen that on the average they are distinctly weaker than the samples of Series **2**.

Series 1.	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(1·67 to 10·27)	6·36	(4)
Albuminoid Nitrogen	(0·38 to 1·37)	0·80*	(4)
Total Organic Nitrogen	(1·05 to 2·07)	1·66	(4)
Total Nitrogen	(2·82 to 12·12)	8·05	(4)
"Oxygen absorbed" at 27°C. (80°F.) *at once*	(1·02 to 2·44)	1·95	(4)
,, ,, ,, ,, *in 4 hours*	(3·65 to 9·27)	6·86	(4)
Chlorine	(3·86 to 14·30)	9·59	(4)
†Solids in Suspension	(8·90 to 28·20)	17·0	(4)
Solids by Centrifuge (vols.)	(52·0 to 80·0)	65·8	(4)
Ratio of Solids in Suspension to Centrifuge Solids	(1 : 1·8 to 1 : 7·5)	1 : 4·7	(4)
"Cellulose" (by alkali, acid and ether)	(1·04 to 2·76)	1·96	(4)
Ratio of "Cellulose" to Solids in Suspension	(1 : 6·3 to 1 : 10·6)	1 : 8·9	(4)

Chance Samples.—In addition to the hourly sets, two chance samples of precipitation liquor were examined. The first of these, No. **3039**, drawn in November, **1902**, at **4·55** p.m., in dry weather, was only about half the average strength; while No. **3085**, drawn in January, **1903**, at **4·20** p.m., during a rapid thaw following heavy snow on the previous night, was exceedingly dilute. It had only a slight sewage smell on the morning of analysis, which disappeared in a few minutes, and the liquid, after filtration through paper, was almost clear. It gave the following figures, among others :—

Albuminoid Nitrogen	0·20
Total Nitrogen	2·06
"Oxygen absorbed" at 27° C. (80° F.) *in 4 hours*	3·13
Solids in suspension	8·0
Incubator Test (by smell)	Failed

The foregoing results are sufficient to show that the Calverley filters have to treat on the average a very strong and poorly settled precipitation liquor, which, however, is subject to great variations in strength.

Bacteriological results.—The bacteriological results are shown in the accompanying table. All the samples of precipitation liquor yielded positive results with ·00001 c.c. (100,000 per c.c.) with the B. Coli, neutral red broth, lactose peptone milk, indol, and bile-salt glucose peptone tests. The B. enteritidis sporogenes test yielded variable results, but most of the samples gave positive results with from ·1 to ·01 c.c. (10 to 100 per c.c.).

* Possibly a little too high.

† The Suspended Solids in Nos. **3005** and **3009** were largely inorganic.

Description of Sample.	B. Coli. test.	N.R. = Neutral red broth test. In. = Indol test. L P.M. = Lactose peptone milk test. B.S. = Bile salt glucose peptone test.	B. Enteritidis sporogenes test.	Remarks.
3001. Calverley precipitation liquor. 10/7/02.	—	L.P.M. = 100,000 B.S. = 100,000	10 not 100	
3005. Calverley precipitation liquor. 11/7/02.	—	—	10 not 100	
3009. Calverley precipitation liquor. 13/7/02.	100,000 (+ indol) (+ clot)	N.R. = 100,000 In. = 100,000 L.P.M. = 100,000 B.S. = 100,000	10 not 100	"Gas" test + ·0001 c.c. (24 hrs. at 20° C.)
3011. Calverley precipitation liquor. 15/7/02.	100,000 (– indol) (+ clot)	N.R. = 100,000 In. = 100,000 L.P.M. = 100,000 B.S. = 100,000	Negative $\frac{1}{10}$ c.c.	
3039. Calverley precipitation liquor. 3/11/02.	—	B.S. = 100,000	100 not 1,000	Number of microbes = 6,500,000 (agar at 37° C.)
3484. Calverley precipitation liquor. 6/7/04.	100,000 (+ indol) (+ clot)	N.R. = 100,000 In. = 100,000 L.P.M. = 100,000 B.S. = 100,000	100 not 1,000	
3489. Calverley precipitation liquor. 7/7/04.	100,000 (– indol) (+ clot)	N.R. = 100,000 In. = 100,000 L.P.M. = 100,000 B.S. = 100,000	10	

FILTERS.

Number - - - - -	3.
Size of each - - -	No. 1, 27 feet by 37 feet 6 inches; No. 2, 33 feet 4 inches by 37 feet 6 inches; No. 3, 34 feet by 37 feet 6 inches.
Depth of Material - - -	3 feet.
Material - - - -	Boiler clinker, graded as follows: Top 6 inches, $\frac{1}{4}$ inch diameter; 9 inches, $\frac{3}{8}$ inch diameter; 9 inches, $\frac{1}{2}$ inch diameter; 12 inches, 2 inches diameter.
Total area - - - - -	391 square yards.
Total cubic content - - -	391 cube yards.
Construction - - - -	There are no walls to the beds; they are constructed by simple excavation in the clayey soil.
Distribution - - - -	One trough down the centre of each bed.

Underdraining.—Each bed is underdrained by means of two rows of three-inch agricultural pipes, running from corner to corner of the bed, and one main drain connecting with these where they cross at the centre, the effluent being thus carried to the outlet valve. The ends of the cross drains are brought up to the surface.

Working.—The method of working the beds during the observations has been as follows:—Between seven and eight in the morning the precipitation liquor is turned into one of the outside beds. In dry weather it fills this bed by the afternoon and then overflows into the second bed, so as to fill the latter during the evening and night. Both beds are run off next morning, and the precipitation liquor is then turned into the other outside bed in the same way, the night sewage again filling the middle bed. In this way each of the outside beds receives one filling of day precipitation liquor every other day, and the night bed one filling of night precipitation liquor every night. In times of wet weather, when the volume of liquid is sufficient to fill more than two beds in the day, the liquor flows over the surface of both the full beds and streams down through the third, the valve of which is left wide open.

This method of working only involves the attendance of a man once a day, to renew the precipitant and let off the two beds, and it has therefore the advantage of being economical; but, on the other hand, it involves a very long and varying period of contact.

Capacity.—The original empty tank capacity of the three beds was 65,981 gallons. The original water capacity, assuming that the material placed in the beds would occupy half the space in the tanks, was therefore 32,990 gallons. The first measurements of capacity were made in July, 1902, and the actual total water capacity at this time, obtained by gaugings made upon all three beds, was found to be 13,050 gallons. After six years working, therefore, at an estimated average rate of ·56 filling for each bed per day, the capacity was 19·7 per cent of the original empty tank capacity and 39·5 per cent of the original water capacity.

In March, 1903, after working for a further nine months at an average of ·55 filling per day, the total bed capacity of the works was found to be 15,320 gallons, *i.e.*, there had apparently been an increase in water capacity. This increase, however, was fictitious, being due to a leakage from one of the beds; the capacities of the other beds were practically the same as at the first measurement. The real capacity of all three filters may therefore be taken to have been virtually the same on this occasion as it was in July, 1902.

The third and last measurement of capacity was made in July, 1904. Between this and the previous gauging in March, 1903, the beds had received on an average ·57 filling per day. The measurement gave a total water capacity of 12,090 gallons, equal to 18·2 per cent. of the original empty tank capacity, or 36·4 per cent. of the original water capacity.

At Calverley, therefore, after ten years' use at a slow rate of filling, and with only one renewal of the surface of the material in 1901, the beds were still in good working order, retaining about 36 per cent. of their real water capacity, or 18 per cent. of the tank capacity.

Amount of precipitation liquor treated by the Beds.—On the basis of the dry weather flow of 12,000 gallons per day, the filters treat the following amount of precipitation liquor:—

Per square yard per 24 hours - - - - -	30·6 gallons.
Per cube yard per 24 hours - - - - - -	30·6 gallons.

Owing to the admittance of surface water to the system, the average flow at Calverley is probably considerably more than 12,000 gallons per day; it might even be double as much. In that case, the amounts treated per square or per cube yard would of course be twice as much as are given above.

Effluents.—Sixteen samples were examined chemically. One of them was a "first flush" and two others were "streaming" effluents, and these will therefore be referred to later. The numbers of the other thirteen were 3040, 3099, 3100, 3132, 3133, 3360, 3361, 3379, 3481, 3482, 3486, 3487 and 3490. The first eight of these were drawn during the winters of 1902-3 and 1903-4, five in dry weather and the other three when the flow was affected by rain; the last five of the thirteen samples were drawn in July, 1904, in dry or practically dry weather. Excepting No. 3,040, which was taken from a bed when practically empty, all the others were drawn at or about mid-flow.

They gave the following results on analysis :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(0·38 to 5·08)	2·67	(10)
Albuminoid Nitrogen*	(0·08 to 0·77)	0·35	(10)
Total Organic Nitrogen	(0·19 to 1·29)	0·68	(6)
Oxidized Nitrogen	(0·00 to 1·19)	0·33	(13)
Total Nitrogen	(0·99 to 6·30)	4·37	(9)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(0·11 to 1·84)	0·92	(13)
" " " " *in 4 hours*	(0·81 to 6·86)	3·57	(13)
Dissolved Oxygen taken up in 24 hours at about 18° C.	(0·23 to over 2·20)	1·14 approx.	(7)
Chlorine	(3·82 to 13·52)	8·99	(12)
Incubator Test (Scudder)		5 passed 3 failed	(8)
Incubator Test (by smell)		4 passed 9 failed	(13)
Smell when drawn		3 good 7 doubtful 3 bad	(13)
Smell when analysed		10 good or fair 2 doubtful 1 bad	(13)
Solids in suspension	(5·28 to 13·90)	8·79	(4)
Solids by centrifuge (vols.)	(10·4 to 241·0)	85·8	(12)
Ratio of solids in suspension to centrifuge solids	1 : 3·5 to 1 : 11·9	1 : 10·4	(4)
c.c. per litre Oxygen in solution	(0·0 to 1·4)	0·3	(7)

The foregoing thirteen samples of effluent may be divided roughly into effluents from stronger and from weaker sewage, the former predominating; those drawn in July, 1904, were all strong. In appearance they varied between an almost colourless and slightly opalescent liquid containing a small amount of deposit (No. 3133) and brownish turbid liquids with much finely divided matter in suspension, the latter being in greater number. Only one of the stronger samples withstood incubation (these, however, contained much suspended matter), while three of the weaker ones did; and in only two cases out of seven was the figure for absorption of dissolved oxygen low, those two representing weak effluents.

The somewhat irregular mode in which the filters at Calverley are worked makes it difficult to differentiate at all sharply between the effluents from day and from night sewage, the two being more or less mixed up. If they could be sharply divided from one another, the night effluent would naturally be the better, as coming from the weaker sewage.

The very long period of contact given at Calverley (in those thirteen samples this varied roughly between 6 and 24 hours) does not of course conduce to the ultimate accumulation of nitrate in the effluents, only three of the samples containing over 0·4

* Possibly rather high in Nos. 3482 and 3487.

part nitric nitrogen on the day of analysis, while seven of them contained none or practically none. At the same time it should be noted that ten out of the thirteen samples had an inoffensive smell when they came to be analysed, so these probably had some nitrate to fall back upon between the times of drawing and of analysis. The long contact, however, apparently helps to break down the suspended solids and to allow of their passing out of the beds in very considerable quantity. Were the Calverley effluents settled before being run into the stream, they would be very greatly improved.

Comparing these effluents with the *second series* of hourly samples of crude sewage and of precipitation liquor, we get the following reductions in figures :—

	Reduction on Crude Sewage.	Reduction on Precipition Liquor.
Total Nitrogen	70 per cent.	62 per cent.
Albuminoid Nitrogen	81 "	68 "
"Oxygen absorbed" *at once*	88 "	74 "
" " *in 4 hours*	88 "	70 "
Solids by centrifuge (vols.)	56 "	+80 "

This comparison is, however, a very loose one, for the chlorine figures are respectively :—

Sewage	15·3
Precipitation Liquor	11·0
Effluent	9·0

The solids, as measured by the centrifuge, give an *increased* figure in the effluent, as compared with the precipitation liquor, but in the former they were twice as flocculent as in the latter.

A few words may be added with regard to the remaining three samples of effluent :—

No. 3131 represents the first flush from the emptying of a bed treating night sewage in dry weather, in March, 1903. This effluent was evidently from a weak sewage. It had a sewage smell when drawn and a clean smell when analysed, but it contained no nitrate and failed to withstand incubation; the suspended solids, as judged by the centrifuge, were about 4 parts per 100,000.

Streaming Effluents.—Nos. 3085A and 3380 represent "streaming" effluents, drawn during cold wet weather, when the beds were treating very dilute precipitation liquor. Some of the figures of analysis for these may be given here :—

Parts per 100,000.	No. 3085A (bed had been streaming for 5 to 6 hours).	No. 3380 (streaming for 21½ hours).
Oxidized Nitrogen	0·41	0·75
Total Nitrogen	1·84	1·34
"Oxygen absorbed' at 27°C. (80°F.) *at once*	0·26	0·19
" " " " " *in 4 hours*	1·93	1·53
Dissolved Oxygen taken up in 24 hours at about 18°C	0·35 *	0·37
Incubator test (by smell)	Passed	Passed
Solids by centrifuge (vols.)	16·0	18·0
c.c. per litre Oxygen in solution	2·5	4·3

* At laboratory winter temperature.

Those two effluents were thus of very fair quality, but it will of course be borne in mind that they resulted from the treatment of very dilute precipitation liquor—so dilute as to allow of this streaming process being successful.

Bacteriological Notes.—The bacteriological results are shown in the accompanying table. The B. coli results varied from 100 to 100,000 per c.c. Two samples contained 100, four samples 1,000, four samples 10,000 and three samples 100,000 per c.c. The neutral red broth, indol, lactose peptone milk, and bile-salt glucose peptone tests yielded somewhat parallel results. As regards the B. enteritidis sporogenes test, nine samples contained less than 10, nine samples less than 100, and only one sample contained 100 spores of this anaerobe per c.c. One sample yielded a negative result with 1 c.c. It appears, however, from the chemical results that some, at all events, of the better effluents were derived from the treatment of dilute precipitation liquor.

Description of Sample.	B. Coli test.	N.R. = Neutral red broth test. In. = Indol test. L.P.M. = Lactose peptone milk test. B.S. = Bile-salt glucose peptone test.	B. Enteritidis Sporogenes test.	Remarks.
3002. Calverley effluent, 10/7/02.	—	L.P.M. = 10000 not 100000 B.S. = 100,000	10 not 100	
3003. Calverley effluent, 10/7/02.		L.P.M. = 100,000 B.S. = 100,000	1 not 10	
3006. Calverley effluent, 11/7/02.	—	—	10 not 100	
3007. Calverley effluent, 11/7/02.	—	—	1 not 10	
3012. Calverley effluent, 15/7/02.	100,000 (– indol) (– clot)	N.R. = 100,000 In. = 100,000 L.P.M. = 100,000 B.S. = 100,000	1 not 10	
3013. Calverley effluent, 15/7/02.	100,000 (+ indol) (+ clot)	N.R. = 100,000 In. = 100,000 L.P.M. = 100,000 B.S. = 100,000	1 not 10	"Gas" test + ·001 c.c. (24 hours at 20°C.)
3040. Calverley effluent, 3/11/02.	—	B.S. = 100,000	10 not 100	3,120,000 microbes per c.c. (agar at 37°C.)
3085B. Calverley effluent ("*streaming*" effluent), 9/1/03.	1,000 not 10,000 (+ indol) (+ clot)	N.R. = 1,000 not 10,000 In. = 10,000 not 100,000 L.P.M. = 1,000 not 10,000 B.S. = 100 not 1,000	10 not 100	"Gas" test + 1 c.c. (24 hours at 20°C.); 50,000 microbes per c.c. (agar at 37°C.)
3099. Calverley effluent, 12/2/03.	—	N.R. = 100,000	10 not 100	
3100. Calverley effluent, 12/2/03.	—	N.R. = 100,000	100 not 1,000	
3131. Calverley effluent, 26/3/03.	10,000 not 100,000 (+ indol) (+ clot)	N.R. = 1,000 not 10,000 In. = 10,000 not 100,000	1 not 10	
3132. Calverley effluent, 26/3/03.	10,000 not 100,000 (– indol) (– clot)	N.R. = 1,000 not 10,000 In. = 10,000 not 100,000	10 not 100	
3133. Calverley effluent, 26/3/03.	1,000 not 10,000 (– indol) (+ clot)	N.R. = 10,000 not 100,000 In. = 10,000 not 100,000	10 not 100	

Description of Sample.	B. coli test	N.R. = Neutral red broth test. In. = Indol test. L.P.M. = Lactose peptone milk test. B.S. = Bile-salt glucose peptone test.	B. Enteritidis Sporogenes test.	Remarks.
3360. Calverley effluent, 20/1/04.	1,000 not 10,000 (+ indol) (+ clot)	N.R. = 1,000 not 10,000	1 not 10	
3361. Calverley effluent, 20/1/04.	100 not 1,000 (+ indol) (+ clot)	N.R. = 100 not 1,000	1 not 10	
3379. Calverley effluent, 9/2/04.	100 not 1,000 (+ indol) (+ clot)	N.R. = 100 not 1,000	Negative 1 c.c.	
3380. Calverley effluent, 9/2/04 ("*streaming*" effluent)	1,000 not 10,000 (– indol) (+ clot)	N.R. = 1,000 not 10,000	1 not 10	
3486. Calverley effluent, 6/7/04.	10,000 not 100,000 (+ indol) (+ clot)	N.R. = 100,000 In. = 10,000 not 100,000 L.P.M. = 100,000 B.S. = 10,000 not 100,000	10 not 100	
3490A. Calverley effluent, 7/7/04.	10,000 not 100,000 (– indol) (– clot)	N.R. = 100,000 In. = 10,000 not 100,000 L.P.M. = 100,000 B.S. = 10,000 not 100,000	10 not 100	
3490B. Calverley effluent, 7/7/04.	100,000 (– indol) (+ clot)	N.R. = 100,000 In. = 100,000 L.P.M. = 100,000 B.S. = 100,000	1 not 10	

Effect of Temperature on the working of the beds.—The observations upon temperature at Calverley have included two sets of measurements taken over two separate weeks, one in 1902 and the other in 1904, and also isolated temperature measurements made during visits to the works.

The conclusion to be drawn from these observations is that the effluent follows the temperature of the sewage and not that of the atmosphere, and that therefore the working of the beds is not, in ordinary weather at any rate, affected by the latter. Owing to a rapid thaw of snow on one occasion when samples were drawn, the sewage arriving at the works had a temperature as low as 4° C., that of the effluent being 5° C.; and on another occasion, as the result of heavy rain in wet weather, the temperature of the sewage was 5·5° C., and the temperature of the effluent 4·5° C. On both occasions, however, any effect which might reasonably have been put down to the low temperature of the liquid was counterbalanced by the dilute character of the precipitation liquor to be treated, both the filter effluents being, if anything, better than usual.

SUMMARY.

The Calverley dry weather sewage is exceedingly strong, excepting as regards suspended solids, which are moderate in amount. Owing, however, to the steep gradient of the main outfall sewer, the fluctuations, both in volume and strength, are quite exceptional. Thus, although the storm overflow is set to come into operation when the flow reaches a rate of about 180,000 gallons (*i.e.*, six times a supposed dry weather flow of 30,000 gallons), rates of flow equal to 350,000 to 400,000 gallons per 24 hours have actually been observed to be treated on the filters for a short time; on the other hand, the largest observed volume treated in 24 hours has been 55,000 gallons. These figures are further instructive as showing that relatively larger increases in volume can be dealt with at small works, without serious difficulty, than would be possible in the case of large works.

Although the method of precipitation at Calverley is cheap, the precipitation itself is not very effective, as much as 12 parts of suspended solids per 100,000 being left in the average dry weather samples of precipitation liquor. The main cause of this high figure is that the first tank is allowed to run for one month without being cleaned and the second for two months, so that they almost become septic tanks. Like the sewage, the precipitation liquor is of course subject to great variations in strength.

The inexpensive construction of the beds, by simple excavation in the clay soil has answered well at Calverley, only one serious leak having occurred during the time of our observations, and this was easily put right. The method of working the filter beds is, like the method of precipitation, very economical as regards labour, but it involves long and irregular periods of contact.

Probably in no case would it be practicable to produce, by single contact, a satisfactory effluent from a sewage so strong as that at Calverley. But that the long contact given there (one filling in 48 hours during dry weather) does effect a very marked purification is proved by the fact that ten out of thirteen samples of effluent had an inoffensive smell when they came to be analysed. Further, the method of working results in the washing out of large quantities of suspended solids from the filter beds, possibly because of "septic" action taking place in these to some extent. Still, the effluent *per se*, could not be considered satisfactory as a final effluent, containing as it does too much suspended matter and being in most cases putrescible upon incubation.

The bacteriological results would almost seem to indicate that prolonged contact may decrease the number of intestinal microbes more than short contact; thus, while the samples of precipitation liquor examined always contained 100,000 B. coli per c.c., some of the samples of effluent gave only 100 to 1,000 per c.c. At the same time, the chemical results point to the fact of the bacteriologically good effluents being derived from the treatment of dilute precipitation liquor. But, whatever the explanation, some of the Calverley effluents were, for a single contact process, remarkably good bacteriologically.

The good results, both chemical and bacteriological, given by the two samples of effluent which resulted from the "streaming" of very dilute precipitation liquor are worthy of note. Though the distribution during this streaming was not very good, only about one quarter of the filter being ponded, it was sufficiently so to produce a satisfactory effluent in the cases mentioned.

When the precipitation tanks are emptied of sludge, there is some nuisance from smell, but, once transferred to the lagoons, the sludge dries quickly, without giving rise to further inconvenience. With this exception, the works at Calverley are practically free from smell.

We should like to take this opportunity of expressing our thanks to Mr. W. Walker, Surveyor to the Calverley District Council, for his help in connection with our work at Calverley.

CATERHAM BARRACKS SEWAGE WORKS.

(War Office.)

1. Situation of Works - - - - - -	¼ mile from Barracks.
2. Method of treatment - - - -	Septic and "cultivation" tank, followed by filtration through percolating filters (Scott-Moncrieff process).
3. Population draining to works during observations - - - - - - -	1,300 (average).
4. Water supply in gallons per head, and whence obtained - - - - - - -	17·7 gallons:—a deep well supply, from the East Surrey Water Co.
5. Number of Latrines - - - - -	60.
5a. Number of W.C's. - - - - -	30.
6. Sewerage system - - - - - -	Separate.
7. Average dry-weather flow in gallons per 24 hours - - - - - - -	17,000.
8. Gallons of sewage, per head, per day - -	13.
9. Character of the sewage - - - - -	Exceptionally strong domestic.
10. Date at which observations began - - -	April, 1902.
11. Age of filters - - - - - -	4 years.
12. Amount of storm water treated - - -	Practically none.
13. Total capacity of tanks in gallons - - -	(1) Primary septic tank, 14,000; (2) Cultivation tank, about 20,000.
14. Total area of filters in yards super - - -	93.
15. Total cubic content of filters in yards cube -	155.
16. Nature of filtering material - - - -	Coke.
17. Gallons of septic liquor treated per yard super per 24 hours - - - - - - -	51.
18. Gallons of septic liquor treated per yard cube per 24 hours - - - - - - -	30·7
19. The final effluent is sent on to - - -	The land and disappears into the chalk subsoil.

CATERHAM BARRACKS.

The Caterham Barracks constitute one of the depôts for His Majesty's Footguards. They are situated high up on the Surrey Downs at Caterham.

The population is a variable one, being sometimes as high as 1,500, and sometimes as low as 800 persons. The estimated average population, however, is about 1,300.

The barracks are served, for the most part, by latrines which are flushed twice a day, these flushings comprising the main proportion of the sewage; but the sewers also receive the discharge of about 30 water-closets, as well as the water from the baths, together with some roof water in time of rain. There are about 60 latrines.

The installation put down for the treatment of this sewage consists of a grit channel; a primary closed septic tank; a secondary septic tank filled with flints, through which the liquid from the primary tank passes by upward flow; four percolating filters; and a small tank filled with large flints for the purpose of removing suspended matter from the filter effluent. It was designed by Mr. Scott-Moncrieff in 1898, and was expected to treat the whole of the dry-weather flow of sewage from the barracks, the volume of which was then estimated at 22,000 gallons per 24 hours.

The secondary septic tank filled with flints, which is called the "Cultivation" tank, was constructed to hold approximately 24 hours' flow of sewage, and the filters were designed to deal with 216 gallons per square yard (130 gallons per cube yard) per 24 hours, or about 20,000 gallons per day on the whole filtering area.

The site of the barracks is flat, but the main sewer which carries the sewage to the filters is laid upon a fair gradient; while at the outfall the land dips down into a deep valley. The 6½ acres of land used for the further treatment of the filter effluent are therefore situated on a steep slope, the tanks and filters being placed almost at the top about a quarter of a mile from the barracks and in open country.

The installation was put before the Commission in December, 1898, by Mr. Scott-Moncrieff, as a complete experimental example of his apparatus for sewage treatment.

FLOW OF SEWAGE.

In times of rain, only roof water finds its way to the sewers proper, the rest of the surface water being carried away by a separate system of drainage. The flow of sewage, however, undergoes large temporary increases at such times.

Since the filters do not receive an increased flow of septic liquor during storms, it has not been thought necessary to make any close estimate of the amount of storm water brought to the works in wet weather. It may be said, however, that the flow of sewage during wet weather is, like the dry-weather flow, subject to large and rapid variations. During the gauging operations carried out in April, 1902, the result of a rainfall of 0·1 inch, extending over about forty minutes, was to increase the rate of flow in the proportion of six to one within a quarter of an hour, and to double the total volume for about an hour and a quarter.

The quantity of storm water treated by the tanks depends greatly upon the time of day during which the rain falls. If it occurs when the latrines are being flushed, a large quantity passes over the main storm-overflow; while, if it takes place during the night, a flow of storm water equivalent to about twenty times the average dry-weather flow of sewage may pass to the tanks for treatment. The reason for this is that the dry-weather flow of sewage is itself subject to extraordinary variations in volume, which often cause an over-flow to come into operation during dry weather.

The flow of sewage was gauged by means of an automatic recorder over a period of seven days, ending April 21st, 1902. The rainfall for the week was 0·13 of an inch (0·03″ on the 14th and 0·10″ on the 19th). As this only added about 1,000 gallons to the total weekly flow, the estimates obtained from the measurements may be taken as correct.

The total flow for the week was approximately 120,000 gallons, and the average daily flow 17,000 gallons. The figure of 17,000 gallons therefore represented approximately the dry-weather flow of sewage from the Caterham Barracks at this time.

The highest day's flow of 20,700 gallons occurred on the Saturday, when the baths were emptied, and the lowest day's flow of 12,500 gallons on the Tuesday, when the usual morning flush from the latrines did not occur.

The hourly variations in flow at Caterham are extreme, the volume of sewage being sometimes increased six-fold in a quarter of an hour; indeed, excepting during the night, the flow is never steady for more than a few minutes. The greatest variations occur at stated hours each day (usually 8 a.m. and 2 p.m.), being occasioned by the periodical flushing of the latrines by men specially told off twice a day for this purpose.

Subsoil Water.—As the night flow during dry weather is very small, it may be taken that little subsoil water gains access to the sewers at such times.

On Diagram D are given some illustrations of the sewage flow at Caterham.

Crude Sewage.—Four sets of hourly samples and one chance sample were examined chemically. The hourly sets, Nos. 12, 17, 22 and 27, were drawn according to rate of flow in the middle of April, 1902, in practically dry weather, the first three sets each representing 48 hours and the last one 24 hours. Excepting in the matter of suspended solids, the last sample was distinctly stronger than the others, but they are all averaged up equally here. If each of the first three was taken as equal to two samples and the last as equal to one sample, the average figures would come out slightly lower than they do (excepting as regards suspended matter), but only slightly (*e.g.*, Total Nitrogen 16·8 instead of 17·5; "Oxygen absorbed" in 4 hours 17·5 instead of 18·0). The chance sample No. "A" was drawn on Tuesday, February 2nd, 1904, at 11.20 a.m.

The following results were obtained:—

Parts per 100,000.		Average.	Number of Estimations.	Chance Sample. — No. A.
Ammoniacal Nitrogen	(11·81 to 16·58)	13·41	(4)	4·05
Albuminoid Nitrogen	(1·36 to 2·21)	1·75	(4)	1·28
Total Organic Nitrogen	(2·34 to 6·32)	3·87	(4)	7·30
Total Nitrogen	(15·18 to 22·90)	17·53	(4)	11·35
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(3·38 to 9·50)	5·70	(4)	7·20
" " at 27° C. (80° F.) *in* 4 *hours*	(13·87 to 21·19)	17·99	(4)	23·59
Chlorine	(10·34 to 17·12)	13·57	(4)	10·48
Solids in Suspension	(31·3 to 62·1)	42·10	(4)	16·40
Containing Mineral Matter	(7·90 to 25·20)	15·30	(4)	4·50
Containing Grit	(13·08 and 7·08)	—	(2)	—
Solids by Centrifuge (vols.)	(173·0 to 247·0)	220·0	(4)	71·0
Ratio of Solids in Suspension to Centrifuge Solids	(1 : 4·0 to 1 : 7·6)	1 : 5·5	(4)	1 : 4·3
"Cellulose" (by Alkali, Acid and Ether)	(7·84 and 4·96)	—	(2)	—
Ratio of "Cellulose" to Suspended Solids	(1 : 7·9 and 1 : 8·7)	—	(2)	—

These sets of hourly samples were rather uneven in composition. The first two sets had only a slight sewage smell on the day of analysis, but the last set had a strong disagreeable odour. The above figures show the exceptionally strong character of the sewage. As regards ammonia, and oxidizable matter (as measured by the 4 hours' "Oxygen absorbed" test), it may be taken as being nearly twice as strong as an average sewage. In the matter of suspended solids, however, it is only slightly above the average; in the first two sets of hourly samples examined, about one-fifth of those solids consisted of grit, which shows that, at any rate in some cases, a separate system does not mean exclusion of grit.

Coming as it does from a barracks, the sewage not only fluctuates largely in volume at different hours of the day, but also varies very much in character. This is very clearly brought out by the figures of analysis of the chance sample examined, No. "A,"—a

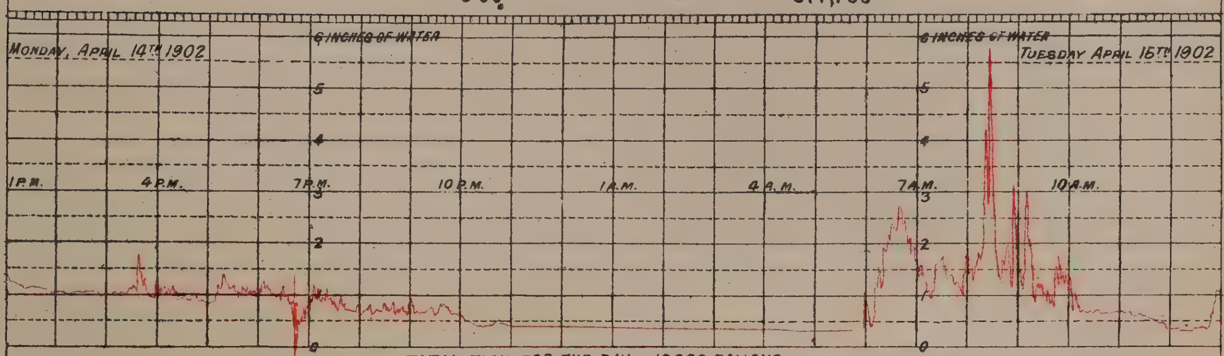
Diagram D.

Diagrams showing Flow of Sewage at Caterham Barracks.

As falling over a Weir 12" wide.

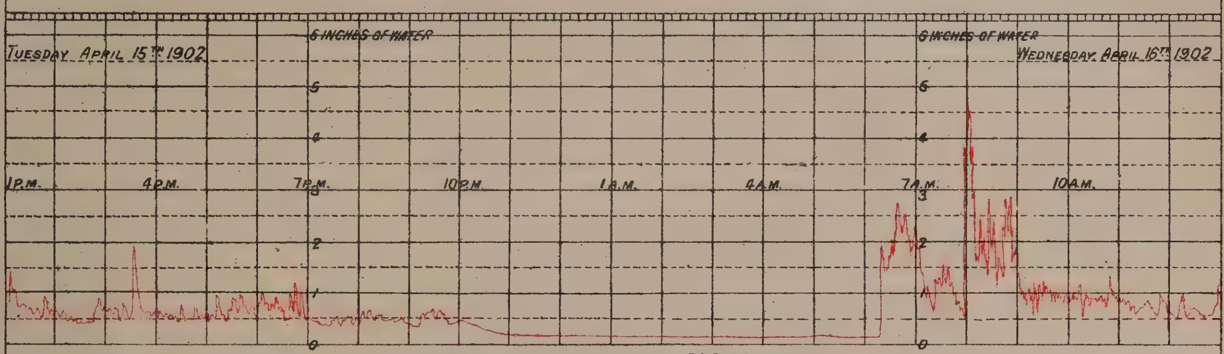
Note:- Over a Weir 12" wide	0·25 inches	= a rate of	5,210	gallons per 24 hours.
	0·50 "	= " " "	14,830	" " " "
	1·00 "	= " " "	41,760	" " " "
	2·00 inches	= " " "	118,080	" " " "
	3·00 "	= " " "	216,000	" " " "
	5·00 "	= " " "	462,240	" " " "
	6·00 "	= " " "	617,760	" " " "

DAY.
FALL
INCH.



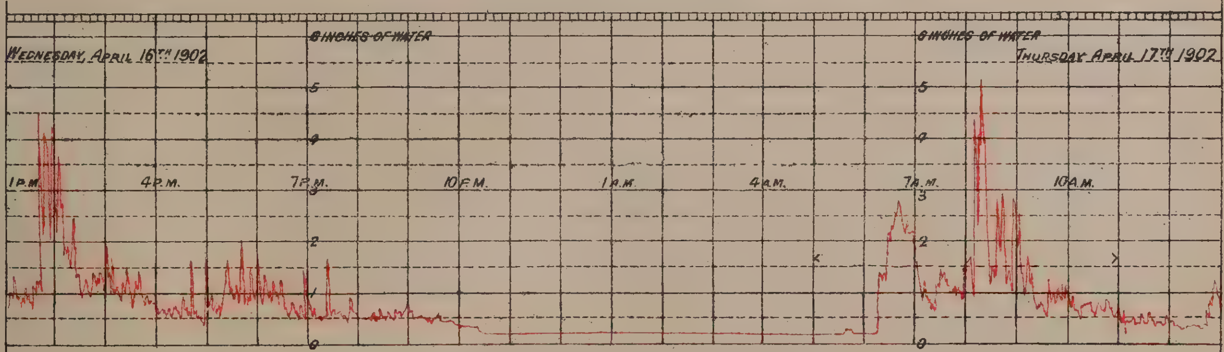
TOTAL FLOW FOR THE DAY = 19,822 GALLONS.

DAY.
LL NIL.



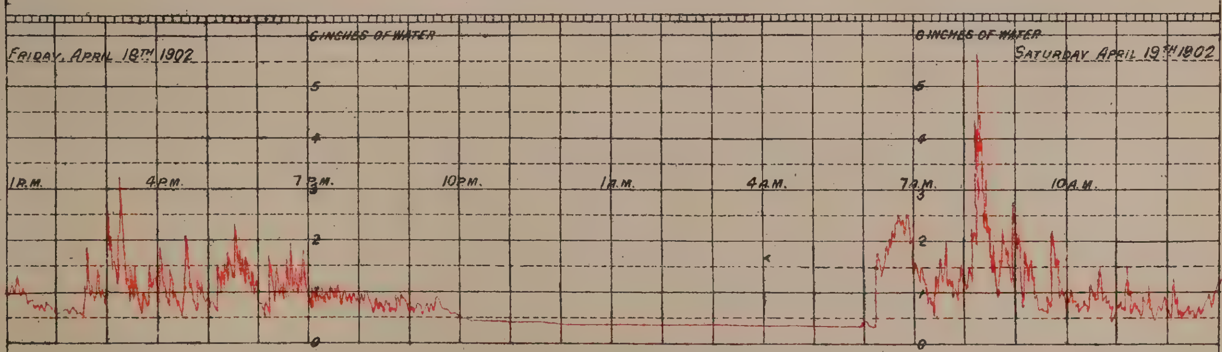
TOTAL FLOW FOR THE DAY = 12,526 GALLONS.

AY.
. NIL.



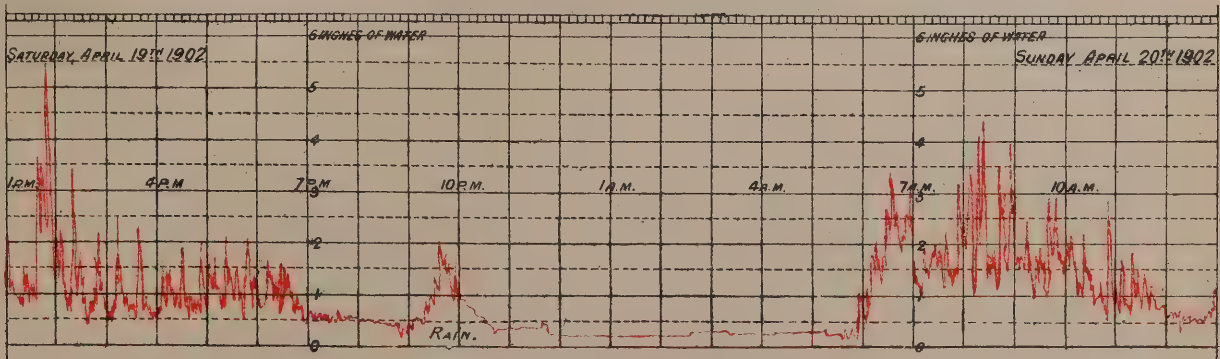
TOTAL FLOW FOR THE DAY = 17,178 GALLONS.

AY.
NIL.



TOTAL FLOW FOR THE DAY = 17,779 GALLONS.

Y
HOWER,
0 INCH.



TOTAL FLOW FOR THE DAY = 20,734 GALLONS

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sample which had a smell of carbolic soap; this, while very high in total nitrogen and oxidizable matter, contained relatively little ammonia and suspended solids. The necessity for equalizing such a sewage before filtration is thus obvious.

Bacteriological Results.—The results of the bacteriological examination of the Caterham crude sewage, tank liquor and effluents, etc., are given in Appendix B.

GRIT CHANNEL.

Immediately after it arrives at the works, the sewage passes into a long grit channel (43 feet by 1 foot 7 inches and 1 foot 6 inches deep), where it deposits its grit and heavy suspended matter. The channel is only very occasionally cleaned, and as the sewage usually arrives in a very unbroken condition, it soon becomes full of a thick and solid sludge. For this reason very little disintegration appears to go on, and the whole mass remains in the channel until it is either carried forward into the first tank, or removed by scooping into barrows and wheeling on to the land. There are no sludge valves to the channel. The removal of this sludge is a very unpleasant process.

It must be stated, however, that this description refers to the channel as worked during our observations. We are not certain whether it was originally intended for grit settlement, and indeed we understand that when the installation was designed, Mr. Scott-Moncrieff contemplated dealing with the sewage from an entirely separate sewerage system, from which grit was excluded.

PRIMARY CLOSED SEPTIC TANK.

Number - - - - - -	1
Capacity - - - - - -	14,000 gallons (approx.)

The sewage and sludge from the grit channel pass into the primary septic tank, where further settlement takes place, that portion of the sludge which is arrested in it assuming a greyish black appearance. The tank is (roughly) 22 feet long, 12 feet wide and 9 feet 6 inches deep. It holds about 14,000 gallons. It is covered with a cement roof.

After running for about three weeks, the primary septic tank usually shows that it is becoming choked with sludge, by the forcing of some of its butter-like scum through a venthole in the cement roof. The sludge is then partially removed by opening a side valve situated about 2 feet below the water level, and some 6 feet above the bottom of the tank. By this means a quantity of about 5,000 gallons of thin sludge is let out, the water level in the primary and "cultivation" tanks being lowered at the same time by about 2 feet and 1 foot respectively. The discharge is accompanied by a considerable smell.

As the bottom part of the primary tank is never emptied, the flow of sewage must be almost entirely confined to the upper part.

"CULTIVATION" TANK.

The liquid, after having passed through the primary tank, is delivered into the bottom of a second tank (42 feet by 20 feet by about 8 feet deep), filled with large flints. This is called by Mr. Scott-Moncrieff the "Cultivation" tank.

The delivery is made by means of a large perforated pipe laid underneath the flints and the tank liquor issues again from three outlets near the surface of the tank in what appears to be a highly septic condition.

Two of the three outlets are overflows into the field, placed at the water level, while the third outlet, which is a short distance below the water level, delivers the liquid to be treated by the filters.

The flow on to the filters is constant or practically so, while that on to the field varies with the flow of sewage.

After running for a period of about three months, the "Cultivation" tank usually becomes rather choked, and the liquor flowing on to the filters begins to contain a large quantity of suspended matter. The valve connecting to the bottom of the tank is

then opened, and the liquid sludge resting in the spaces between the lower flints is discharged on to the hillside. With the valve open to its fullest extent, the operation takes about an hour, and is attended with a very offensive smell. Owing to the porous nature of the soil, however, the smell passes off within a day, if the weather is dry.

A rough estimate of the volume of liquid sludge which was run out of the "Cultivation" tank on June 3rd, 1902, gave 9,500 gallons.

Septic Tank Liquor from the Cultivation Tank.—Eight sets of hourly samples and eight chance samples of septic tank liquor were examined chemically; these must however be sub-divided into samples of:—(A) *Field Tank Liquor, i.e.* the excess of liquor which is not treated on the filters, but allowed to pass direct on to the land, and (B) *Filter Tank Liquor*, which is treated on the filters.

(A) *Field Tank Liquor.*—The four hourly sets of this, Nos. 13, 18, 23 and 28, were drawn at the same time as the hourly samples of sewage, in practically dry weather, according to rate of flow, the first three representing 48 hours each and the last one 24 hours. In the third sample, No. 23, there were no fractions, *i.e.*, no field tank liquor from 4 p.m. on the 18th to 6 a.m. on the 19th, inclusive. At the time these samples of tank liquor were drawn, the tank had been in use, without being sludged, for about one month.

Beside the figures for the hourly samples are given those for the two chance samples Nos. 5 and 9, drawn on January 10th and 22nd, 1902, about 1 p.m. Excepting in the matter of suspended solids, these two samples were very similar to one another in composition.

Hourly Samples.	Parts per 100,000.	Average.	Number of Estimations.	Chance Samples Nos. 5 and 9. Average Figures.
Ammoniacal Nitrogen	(15·91 to 19·30)	18·09	(4)	16·48 (2)
Albuminoid Nitrogen	(1·19 to 1·47)	1·38	(4)	2·45 (2)
Total Organic Nitrogen	(2·71 to 4·40)	3·35	(4)	5·04 (2)
Total Nitrogen	(20·11 to 22·45)	21·14	(4)	21·53 (2)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(4·28 to 4·99)	4·67	(4)	7·40 (2)
"Oxygen absorbed" at 27° C. (80° F.) *in 4 hours*	(13·42 to 14·34)	13·89	(4)	16·42 (2)
Chlorine	(11·64 to 14·60)	13·23	(4)	13·47 (2)
Solids in Suspension	(20·1 to 30·0)	25·40	(4)	34·80 (2)
Containing Mineral Matter	(3·7 to 6·2)	5·10	(4)	8·50 (2)
Containing Grit	(1·58 and 2·78)	—	(2)	1·16 (1)
Solids by Centrifuge (vols.)	(91·0 to 160·0)	116·0	(4)	202·0 (2)
Ratio of Solids in Suspension to Centrifuge Solids	1 : 3·0 to 1 : 5·5	1 : 4·6	(4)	1 : 6·3 (2)
"Cellulose" (by Alkali, Acid and Ether)	(4·04 and 4·04)	—	(2)	2·56 (1)
Ratio of "Cellulose" to Suspended Solids	1 : 5·0 and 1 : 5·5	—	(2)	1 : 10·4 (1)

In appearance all these samples of septic tank liquor were turbid and brownish, with sediment varying in colour from grey to black, and of different degrees of flocculence. All excepting one had a strong septic tank odour. The highly nitrogenous and especially ammoniacal character of this liquor is apparent from the analysis, while the figures for "oxygen absorbed" and also those for suspended solids are very high. The "cultivation" tank filled with flints, therefore, while inducing a strong septic action in the concentrated sewage, yields a very poor result so far as the retention of the suspended solids is concerned.

Compared with the hourly samples of sewage, the above hourly samples of "Field" tank liquor show the following differences in figures :—

Total Nitrogen	21 per cent. increase.
Ammoniacal Nitrogen	58 " "
Albuminoid Nitrogen	21 " reduction.
Total Organic Nitrogen	13 " "
"Oxygen absorbed" *at once*	16 " "
" " *in 4 hours*	23 " "
Solids in Suspension	40 " "
Mineral Matter in those Solids	67 " "
Solids by Centrifuge (vols.)	47 " "
"Cellulose"	37 " "

Even allowing for the fact that the above comparison of the sewage and the septic tank liquor is not strictly correct, it is evident that a considerable decomposition of the organic nitrogenous matter in the tanks was going on at the time, judging from the large increase in the quantity of ammonia. The solids in suspension were only reduced by about 40 per cent., but the mineral matter of those solids by 67 per cent.

The two chance samples of "Field" tank liquor examined contained more matter in suspension (43·0 and 26·6 parts respectively), but they were otherwise of the same character as the hourly samples.

Nothing further requires to be said to demonstrate the exceptional strength of this septic tank liquor.

(B) *Septic Tank Liquor going on to Filters* :—The four sets of hourly samples of this, Nos. 14, 19, 24 and 29, were drawn at the same time as the hourly samples of "Field" tank liquor, in the middle of April, 1902, in almost dry weather, but *in equal quantities* every hour, the object of this being to allow of a comparison with the filter effluents.

The first three sets each represented 48 hours' flow and the last one 24 hours ; in No. 14, however, the fractions for 4, 5 and 6 p.m. for one day were missing, in No. 19 the fractions for 3, 4 and 5 p.m., while in No. 24 the fractions from 4 p.m. on the 19th to 7 a.m. on the 20th had to be omitted. The last set was complete.

They gave the following figures on analysis :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(15·94 to 20·65) (?)*	18·48†	(4)
Albuminoid Nitrogen	(0·96 to 1·29)	1·06	(4)
Total Organic Nitrogen	(3·12)	—	(1)
Total Nitrogen	(18·14 to 21·59)	20·14	(4)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(3·24 to 4·77)	3·73	(4)
" " at 27° C. (80° F.) *in 4 hours*	(8·91 to 11·90)	10·15	(4)
Chlorine	(11·50 to 14·76)	13·31	(4)
Solids in Suspension	(9·50 to 16·30)	12·60	(4)
Containing Mineral Matter	(0·30 to 2·10)	1·10	(4)
Containing Grit	(0·80 to 1·26)	1·06	(3)
Solids by Centrifuge (vols.)	(33·0 to 74·0)	47·0	(4)
Ratio of Solids in Suspension to Centrifuge Solids	1 : 2·8 to 1 : 4·5	1 : 3·7	(4)
"Cellulose" (by Alkali, Acid and Ether)	2·48 to 3·36	2·96	(3)
Ratio of "Cellulose" to Suspended Solids	1 : 3·1 to 1 : 5·1	1 : 4·3	(3)

* Probably too high. † Slightly too high.

In appearance and general character these samples were, of course, similar to the hourly samples of "Field" tank liquor; but, while the total nitrogen was almost the same in both, the "Filter" tank liquor contained only half as much suspended matter, and this in its turn had relatively less mineral matter. The two series cannot be rigidly compared with one another, having been sampled on different plans, but it is obvious that the method of drawing off resulted in much the larger proportion of the suspended matter of the liquor passing on to the land. Notwithstanding this, the liquid which the filters at Caterham have to treat is an abnormally strong one, especially as regards ammonia, while it also contains a large amount of matter in suspension.

The six chance samples of "Filter" septic tank liquor examined chemically, Nos. 2, 6, 10, 3106A, 659 and "B" were all drawn during the winter months (1901-4).

They gave the following figures:—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(15·32 to 26·18)	19·22	(5)
Albuminoid Nitrogen	(1·28 to 2·08)	1·62	(5)
Total Organic Nitrogen	(3·48 to 5·83)	4·59	(5)
Total Nitrogen	(20·26 to 29·66)	23·71	(6)
"Oxygen absorbed" at 27°C. (80°F.) *at once*	(4·06 to 5·54)	4·87	(6)
" " " " *in 4 hours*	(13·18 to 19·96)	16·49	(6)
Chlorine	(10·41 to 17·78)	14·31	(5)
{ Solids in Suspension	(19·8 and 13·5)	—	(2)
{ Containing Mineral Matter	(4·4 and 4·5)	—	(2)
Solids by Centrifuge (vols.)	(37·0 to 120·0)	60·2	(6)
Ratio of Solids in Suspension to Centrifuge Solids	(1 : 6·1 and 1 : 2·7)	—	(2)

The above chance samples naturally varied more in composition than the hourly ones, the variations being considerable but not extreme. All of the samples had a strong septic tank smell when analysed. Judging from the centrifuge figures, they contained more suspended solids than the hourly samples (say, about 16 parts), while the average figure for "oxygen absorbed" in 4 hours was also very high (16·5). They thus serve to confirm what has been already said under the hourly samples—that the liquid treated upon the filters at Caterham is always an exceedingly strong one in every respect. One or two notes may be added with regard to individual samples:—

No. 3106A. was drawn only two or three days after the primary tank had been sludged, and yet it gave a centrifuge figure of 64.

The centrifuge figures for the *Field* tank liquors, Nos. 5 and 9, were 174 and 230 respectively, while those for the two *Filter* tank liquors drawn at the same time, Nos. 6 and 10, were 65 and 120. This further bears out what was said under the hourly samples, viz., that much the larger proportion of the suspended matter of the tank liquor passes on to the land.

Though no estimations of colloidal matter were made in the Caterham tank liquor, judging from its appearance it probably contained a large quantity.

FILTERS.

Number	4.
Size of each	11 feet by 9 feet 6 inches.
Area of each	23·22 square yards.
Total Area	93 square yards.
Depth of material	5 feet.
Total cubic content	155 cube yards.

The "Aerating Trays," as the filters are called, are arranged in the form of four filters, each consisting of seven concrete trays, perforated at the bottom and filled with coke. The coke is graded from $\frac{3}{8}$ of an inch in diameter in the uppermost tray to about 3 inches diameter in the lower ones.

The distribution of tank liquor is effected by the tipping of four troughs, which each discharge about fifteen gallons of liquid into perforated pipes extending over the surface of the material. At the ordinary rate of flow the discharges take place about once in twenty minutes. If the distributing pipes are kept clean, the method is very effective; but they need constant attention, and require to be brushed and picked out at least twice a week when the flow is at the normal rate.

The total time which is spent in cleaning the primary tank and the pipes each week is about twelve or fourteen hours for one man. During this time the filters are out of work, and the whole of the tank liquor goes to the land.

The filters themselves need little attention, the uppermost trays requiring only occasional raking; the lower ones are not touched.

The flow of tank liquor on to the filters, which, by reason of the troughs, is intermittent, was very carefully gauged throughout a week in April, 1902, and was found to be at the rate of 51 gallons per square yard, or 30·7 gallons per cube yard per day, giving a mean quantity of 4,740 gallons per day, treated upon the total filtering area of 93 square yards. This was rather less than one-third of the total flow of sewage during the week.

The filters have shown no signs of clogging throughout the whole of our observations, and we are further told that the coke has never been changed since the installation was brought into use in September, 1898.

Unsettled Effluents.—Four hourly and nine chance samples of these were examined chemically. The hourly sets, Nos. 15, 20, 25 and 30, were drawn in equal quantities every hour at the same time as the other hourly samples, *i.e.*, from April 14th to 21st, 1902, in almost dry weather. The first three each represented 48 hours flow and the last one 24 hours, excepting that the same fractions were omitted from the first three sets as in the case of the hourly samples of "Filter" tank liquor.

The following results were obtained:—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(5·76 to 7·91)	6·77	(4)
Albuminoid Nitrogen	(0·32 to 0·49)	0·42†	(4)
*Oxidized Nitrogen-	(8·49 to 9·57)	8·90	(4)
Containing Nitrous Nitrogen	(0·33 to 0·87)	0·68	(4)
Total Nitrogen	(15·72 to 17·04)	16·75	(4)
"Oxygen absorbed" at 27° c. (80° F.) *at once*	(1·75 to 2·20)	1·92	(4)
" " " " *in 4 hours*	(4·63 to 5·64)	5·22	(4)
Incubator Test (Scudder)		2 +	(2)
Incubator Test (by smell)		4 +	(4)
Smell when drawn		4 +	(4)
Smell when analysed		3 +	(3)
Chlorine	(10·46 to 12·80)	11·35	(4)
Solids in Suspension	(2·6 ? to 4·2 ?)	3·7 ap.	(4)
Solids by Centrifuge (vols.)	(67·0 to 106·0)	84·0	(4)
Ratio of Solids in Suspension to Centrifuge Solids	(1 : 16·6 and 1 : 20·5)	—	(2)

* In these analyses, as well as in the first five of the chance samples of unsettled effluent, the figures for Oxidized Nitrogen are only to be taken as correct to within one or two tenths of a part; they may possibly be a trifle too high. For this reason no figures are given for Total Organic Nitrogen in these samples.

† Possibly a little too high.

These effluents were of very even composition. In appearance they were all yellow-brown in colour, and they had in suspension considerable quantities of very flocculent brown suspended solids. They had all a clean smell when drawn and when analysed,* while they all readily withstood incubation. If the figures for total nitrogen in these effluents be compared with those given by the hourly sets of "Filter" septic tank liquor, it will be seen that the actual diminution has only been from 20·1 to 16·7 parts, but that half of the nitrogenous matter has been oxidized to nitrite and nitrate. The large quantity of nitrite (average 0·68 part) found in those effluents on the day of analysis was a marked feature, and nitrite was also present to a considerable extent after incubation. The figure for "oxygen absorbed" from permanganate in 4 hours was high (5·22). The suspended solids were estimated in this case by difference and the figures are probably rather low, in consequence, but these solids were of a very flocculent character. Judging from the clean state of the coke in the trap at the time, practically all the solids of the tank liquor, which were undigested, passed through the filtering material, and the issuing solids probably contained as much mineral matter as those going on, though our analyses are too few to allow of a definite statement here. No estimations of the absorption of dissolved oxygen by those effluents were made, except that they were aerated, by shaking, before being despatched to the laboratory, and next morning three out of the four showed some oxygen by the copper chloride method. The rate of absorption of oxygen was thus not very rapid (of chance samples).

The ammoniacal and organic matter of the exceptionally strong tank liquor treated in the filter trays was thus oxidized to the extent of about two-thirds—if this expression may be allowed—but the oxidizing process was not by any means carried to its full extent. At the same time a highly nitrated and inoffensive effluent, which readily withstood incubation, was produced. The large quantity of nitrate present in this effluent must make it excellent for irrigation purposes.

Compared with the hourly samples of "Filter" septic tank liquor, with which they are strictly comparable, those effluents show the following reduction in figures :—

Calculated on :—	Reduction.
Total Nitrogen	17 per cent,
Ammoniacal Nitrogen	63 " " ap.
Albuminoid Nitrogen	60 " "
"Oxygen absorbed" *at once*	48 " "
" " *in 4 hours*	49 " "
Solids in Suspension	61 " " ap.

The eight ordinary chance samples of unsettled effluent examined were Nos. 7, 32, 34, 36, 38, 660, "C" and 3,548. The first five of these were drawn between January and April, 1902, and the last three in January, February and October, 1904, *i.e.*, they were all cool weather samples.

They gave the following figures :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(7·01 to 13·03)	8·88	(5)
Albuminoid Nitrogen	(0·27 to 0·54)	0·41	(4)
Oxidized Nitrogen	(3·18 to 10·11)	7·95	(8)
Containing Nitrous Nitrogen	(0·35 to 1·05)	0·72	(7)
Total Nitrogen	(11.84 to 18·77)	16·02	(5)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(1·31 to 1·89)	1·68	(7)
" " " " *in 4 hours*	(3·76 to 8·66)	5·11	(7)
Dissolved Oxygen taken up in 24 hours at about 18° C.	(0·57 to 0·93 ap.)	0·80	(3)
Incubator Test (Scudder)		7 + practically	(7)
Incubator Test (by smell)		7 +	(7)
Smell when analysed		7 +	(7)
Chlorine	(10·34 to 12·74)	11·77	(4)
Solids in Suspension	(2·6 to 5·2)	3·7	(4)
Solids by Centrifuge (vols.)	(20·0 to 174·0)	63·0	(8)
Ratio of Solids in Suspension to Centrifuge Solids	(1 : 11·8 to 1 : 14·4(?))	1 : 12·6	(4)
*c.c. per litre.** Oxygen in solution when analysed	(2·3 to 3·0)	2·6	(3)†

* Not noted in one case, but it may be inferred.
† All the other five effluents also contained some oxygen on the day of analysis.

In general character and appearance those effluents were the same as the hourly samples already described. One of them, No. 660, was noted as having a sewage smell when drawn (with sewage weed showing in the effluent pipe at the time), but all the others may be taken as having been inoffensive with regard to smell, though this was only noted in one case. They all had a clean smell when analysed, and all withstood incubation.

The average figures given by the chance samples are almost the same as the average of the hourly ones, but in the former the individual variations are appreciably greater. On one occasion the total nitrogen fell to 12 parts, while in the last sample the "oxygen absorbed" in 4 hours was as high as 8·66. Two of the samples contained only 3·4 and 4·5 parts of oxidized nitrogen, but all the others had over 8 parts. The suspended solids also showed great differences, as judged by the centrifuge figures (from 20 to 174 vols.), say, from 1·5 to 12 parts, but as a rule they would be about 4 parts. The nitrite was again very high, both in the original and incubated liquids—a sign of incomplete oxidation.

All the effluents contained some dissolved oxygen when they came to be analysed, but the absorption of dissolved oxygen was only estimated accurately in the last three samples: the figures so obtained are interesting when compared with those for "oxygen absorbed" from permanganate:—

——	No. 660.	No. "C."	No. 3,548.	
			Original.	Filtered through paper.
"Oxygen absorbed" from Permanganate in 4 hours at 27° C.	5·37	3·76	8·66	3·42
Dissolved Oxygen taken up from Water in 24 hours at about 18° C.	0·93*	0·90	0·57	0·07
Solids in Suspension	—	3·50	2·60	—
Solids by Centrifuge (vols.)	20·0	50·0	30·6	—

The above figures for absorption of dissolved oxygen, though high, are relatively low when compared with the figures for permanganate absorption; this again illustrates the point that an effluent from a *strong* sewage may give a comparatively high figure for "oxygen absorbed," although it may not contain much organic matter of a readily putrefactive character. The illustration would have been more pointed had the three effluents in question been rather better purified. Further, the difference in the figures for both permanganate and for dissolved oxygen absorption given by No. 3,548, (*a*) as drawn, and (*b*) after filtration through paper, is very marked, the liquid portion of the effluent showing practically no further tendency to take up oxygen in 24 hours.

No. 788 was an interesting sample. It was drawn on Wednesday, March 22nd, 1905, in dry weather, the filter having been just re-started after a stoppage of less than a day. It contained such an unusual quantity of suspended solids that it was analysed both as a whole and after settlement for two hours, with the following results:—

——	Original Sample.	After 2 Hours' Settlement.
Ammoniacal Nitrogen	—	13·10
Albuminoid Nitrogen	—	—
Nitrous Nitrogen	—	1·02
Nitric Nitrogen	—	2·98 ap.
Total Nitrogen	21·37	19·12
"Oxygen absorbed" at 27° C. (80° F.) *at once*	4·43	3·08
" " " " *in 4 hours*	13·57 †	8·71
Dissolved Oxygen taken up in 24 hours at about 18°C.	over 2·80	at least 2·84
Incubator Test (Scudder)	+	+
Incubator Test (by smell)	+	+
Smell when analysed	+	+
Solids in Suspension	32·6	5·0
Solids by Centrifuge (vols.)	412·0	28·8
Ratio of Solids in Suspension to Centrifuge Solids	1 : 12·6	1 : 5·8

* Temperature of incubator fell to 15·5°C., so this figure is a little too low. † $4\frac{1}{2}$ hours.

The suspended solids in the above sample were reddish-brown in colour and the effluent still remained turbid after the two hours' settlement, although there was not much apparent suspended matter left in it. This sample illustrates the marked effect of a short rest in loosening the suspended solids in the filtering material. Even the settled effluent was of very indifferent quality, although the nitrate present enabled both it and the original sample to withstand incubation.

EFFLUENT FLINT TANK.

The effluent from the filter trays is passed through a small tank (22 feet long, 7 feet wide, and 1 foot 7 inches deep), filled with flints, the flow through, on the assumption that the flints occupy about 50 per cent. of the tank space, being about once in 4·5 hours. This is now used for the purpose of straining out the suspended matter in the filter effluent, though, we understand, it was primarily intended for the purpose of denitrification*. The liquid emerges from this tank as the final effluent.

Once a month the valves at the foot of the effluent flint tank are opened, to allow of the accumulated solids being run out on to the field.

Final Effluents.—Four sets of hourly samples and eleven chance samples were examined chemically. The hourly sets, No. 16, 21, 26 and 31, were drawn at the same time as the hourly samples of unsettled effluent and "Filter" tank liquor, and corresponded exactly to these. They gave the following results on analysis :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(5·95 to 8·51)	6·84	(4)
Albuminoid Nitrogen	(0·29 (?) to 0·36)	0·33	(4)
†Oxidized Nitrogen	(7·73 to 9·64)	8·52	(4)
Containing Nitrous Nitrogen	(0·37 to 0·66)	0·57	(4)
Total Nitrogen	(15·31 to 17·44)	16·24	(4)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(1·29 to 1·81)	1·50	(4)
" " " " *in 4 hours*	(3·47 to 4·25)	3·77	(4)
Incubator Test (Scudder)		3 +	(3)
Incubator Test (by smell)		4 +	(4)
Smell when drawn		4 +	(4)
Smell when analysed		4 +	(4)
Chlorine	(10·44 to 12·24)	11·58	(4)
Solids in Suspension	(trace to 1·7 ?)	0·80 (?)	(3)
Solids by Centrifuge (vols)	(trace to 14·0)	8·0	(4)

These final effluents were very uniform in composition; they were yellow to brown in colour, but practically clear, and they contained very little matter in suspension—probably under 1 part per 100,000. They all had a clean smell, both when drawn and when analysed, and all readily withstood incubation. The final flint tank, through which the unsettled effluent passes, fulfils its purpose of removing the suspended matter from the unsettled effluent very well. The liquid portion of the effluent is substantially the same in character and appearance as that of the unsettled effluent.

If the foregoing average figures of analysis be compared with those of the hourly samples of unsettled effluent, it will be seen that the suspended solids are reduced from about 4 parts to 1 part or under, and the 4 *hours* "Oxygen absorbed" figure from 5·22 to 3·77. The oxidized nitrogen also shows a slight reduction, no doubt from the deoxidizing action of the gradually accumulating sludge in the small flint tank; this sludge contains many small worms, and is, of course, in itself putrescible.

* "Sewage and Sewage Purification," by S. Rideal, 1st Edition, page 228.

† In these analyses, as well as in the first seven of the chance samples, the figures for oxidized nitrogen are only to be taken as correct to within one or two tenths of a part; they may possibly be a trifle too high. For this reason no figures are given for the total organic nitrogen in those samples.

Compared with the hourly samples of "Filter" tank liquor, the hourly samples of final effluent show the following reduction in figures:—

Calculated on:—	Reduction.
Total Nitrogen	19 per cent.
Ammoniacal Nitrogen	63 " approx.
Albuminoid Nitrogen	69 "
"Oxygen absorbed" *at once*	60 "
" " *in 4 hours*	63 "
Solids in Suspension	90 " or over.

The actual percentage reduction, therefore, of the organic impurity of the very strong septic tank liquor treated on the filter trays was fairly good, and at the same time a preponderating quantity of nitrate was left in the effluent.

It is impossible to compare accurately the figures of analysis given by the hourly samples of sewage and the hourly samples of final effluent, the former having been drawn according to rate of flow, and the latter in equal quantities every hour; but by combining the reduction given by the hourly samples of "field" tank liquor upon the sewage with that given by the hourly samples of final effluent upon the "filter" tank liquor, the following reduction figures are obtained. They may probably be taken as approximately correct:—

Calculated on:—	——
Total Nitrogen	No reduction.
Ammoniacal Nitrogen	79 per cent. reduction.
Albuminoid Nitrogen	76 " "
"Oxygen absorbed" *at once*	66 " "
" " *in 4 hours*	72 " "
Solids in Suspension	94 " " approx.

Chance Samples.—The eleven ordinary chance samples examined chemically were Nos. 4, 8, 11, 33, 35, 37, 39, 3106 b, 661, D, and 787. The first seven were drawn between December, 1901, and April, 1902, and the remaining four in February, 1903, January and February, 1904, and March, 1905. They were thus all taken in the cooler months of the year.

No. 4 was a sample drawn after the filter had been draining for an hour and a half. It did not, however, differ in composition from the others, and is therefore included with them here.

The following figures were obtained:—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(6·06 to 13·02)	9·21	(9)
Albuminoid Nitrogen	(0·27 to 0·46)	0·35	(7)
Total Organic Nitrogen	(0·72 to 1·49)	1·12	(3)
{ Oxidized Nitrogen	(3·26 to 9·89)	6·67	(11)
{ Containing Nitrous Nitrogen	(0·26 to 0·87)	0·56	(11)
Total Nitrogen	(11·07 to 19·47)	16·32	(8)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(0·98 to 1·96)	1·44	(11)
" " " " *in 4 hours*	(2·93 to 5·62)	4·03	(11)
Dissolved Oxygen taken up in 24 hours at about 18° C.	(0·43 to 0·89)	0·60	(4)
Incubator Test (Scudder)	9 + 2 −		(11)
Incubator Test (by smell)	11 +		(11)
Smell when analysed	11 +		(11)
Chlorine	(10·90 to 14·26)	12·57	(10)
Solids in Suspension	(2·54)		(1)
Solids by Centrifuge (vols)	(trace to 52·0)*	14·0	(11)
c.c. per litre			
Oxygen in Solution when analysed	(trace to 1·2)	0·4	(4)

* This was a quite exceptionally high figure; the next highest was 20.

These chance samples of final effluent had, of course, the same yellow to brown colour as all the others, but they were on the whole rather more turbid than the hourly samples. They may be taken as having had an inoffensive smell when drawn, and they had all a clean—often a strong earthy—smell when analysed. Again, all of them withstood incubation. No. 37 gave the high centrifuge figure of 52, but from all the others the suspended solids had been well separated, probably averaging not more than about 1 part per 100,000. The average figure for total nitrogen was almost identical with that of the hourly samples, and excepting for one case (11·07), it was consistently very high. The average for oxidized nitrogen was rather less, and for ammoniacal nitrogen rather greater in the chance samples; nitrite was again present in quantity. The oxidation was much less pronounced in the last four samples, examined in 1903–5, the average figure for oxidized nitrogen in these being 4·3, as against an average of 8·0 in the first seven samples, drawn in 1901–2.

Four of these chance samples of final effluent, Nos. 4, 8, 35 and 39, were also examined partially after being mercury-jointed and incubated at 27° C. (80° F.) for periods of time varying from six weeks to six days. The following were the *averages* of the comparative figures obtained:—

———	Original Sample.	Incubated Sample.
Ammoniacal Nitrogen - - - - - -	7·42 (2)	7·36 (2)
Albuminoid Nitrogen - - - - - -	0·29 (2)	0·22 (2)
Nitrous Nitrogen - - - - - -	0·65 (4)	0·44 (4)
Nitric Nitrogen - - - - - - -	7·66 (4)	7·49 (4)
"Oxygen absorbed" *in 4 hours* - - - -	1·17 (2)	0·79 (2)

These samples had thus undergone comparatively little change during the incubation; the oxidized nitrogen was reduced by 0·63 part* approximately, and the 4 hours "oxygen absorbed" figure by 0·38. The samples were thus very stable.

Compared with the hourly samples of "Filter" tank liquor, the chance samples of final effluent show the following reduction in figures:—

Calculated on	———	Number of Estimations in Effluent.
Total Nitrogen - - - - - - -	20 per cent. reduction.	(8)
Ammoniacal Nitrogen - - - - -	50 „ „ approx.	(9)
Albuminoid Nitrogen - - - - - -	70 „ „	(7)
"Oxygen absorbed" *at once* - - - - -	61 „ „	(11)
„ „ *in 4 hours* - - - -	60 „ „	(11)

* The figures for oxidized nitrogen are only to be taken as correct to within one or two tenths of a part; they may possibly be a trifle too high.

The following figures are of some interest, mainly as illustrating the rate of absorption of dissolved oxygen by several of the effluents, over different lengths of time and at different temperatures :—

——	Unsettled Effluents.			Final Effluents.		
	C.	3548.		3106B.	D.	787.
	—	Original.	Filtered through Paper.	—	—	—
Total Nitrogen - - -	11·84	15·43	—	—	11·09	19·47
"Oxygen absorbed" *at once*	1·31	1·57	1·54	1·46	1·13	1·96
"Oxygen absorbed" *in* 4 *hours*	3·76	8·66	3·42	4·53	2·93	5·62
Solids in Suspension - -	3·50	2·60	—	—	—	—
Solids by Centrifuge (vols.)	50·0	30·6	—	20·0	2·9	3·6
Dissolved Oxygen taken up from water at about 18° C. in 24–96 hours. - -	hrs. 24, hrs. 48, hrs. 72, hrs. 96 0·90 1·58 — 2·52	hrs. 24, hrs. 48 0·57 1·39	hrs. 24, hrs. 48 0·07 0·21	hrs. 24 0·43	hrs. 24, hrs. 48, hrs. 72 0·58 0·91 1·24	hrs. 24, hrs. 48 0·89 2·16*

The above figures show that while the rate of absorption of dissolved oxygen by the Caterham effluents is generally rather high in the first instance, it is as a rule less on the second day than on the first, and so on (No. 787 was an exception to this, but it was rather an abnormal sample, collected soon after restarting the filters, subsequent to a day's stoppage). They also show, as has already been stated, that the absorption of dissolved oxygen in 24 hours is *relatively* small as compared with the "oxygen absorbed" from permanganate.

One or two figures, showing the absorption of dissolved oxygen by two of the final effluents, for different lengths of time at different temperatures, may also be given, though they are contradictory :—

——	Final Effluents.	
	No. 661.	D.
"Oxygen absorbed" *in* 4 *hours* - - - - - - - - - -	4·59	2·93
Dissolved Oxygen taken up :—		
(*a*) in 24 hours at 18°C. (65°F.) - - - - - - - - -	0·57*	0·58
(*b*) in 6 hours at 27°C. (80°F.) - - - - - - - - -	0·14	0·58
(*c*) in 4 hours at 37°C. (99°F.) - - - - - - - - -	0·11	0·50

These estimations were done with the object of seeing whether the 24 hours allowed for the dissolved oxygen absorption test might be shortened, if the temperature was raised so as to allow of the test being carried out within the limits of an ordinary working day.

Experiments with an Increased Flow of Tank Liquor on to the Filters.—Having ascertained the nature of the final effluent when the filters were taking a flow of 4,700 gallons per day (*i.e.*, 30·7 gallons per cube yard per day), we thought that it would also be of interest to test the effect of an increased flow of tank liquor. With the sanction of the authorities, therefore, we made two experiments for this purpose. In the first one (*a*), which lasted for a month (May 2nd to June 3rd, 1902), the filters were made to treat double the original flow of tank liquor. One result of this was to necessitate the cleaning of the distribution pipes three times a week instead of twice, and the emptying of the effluent flint tank twice in a month instead of once.

In the second experiment (*b*), which lasted for three weeks (June 3rd to 23rd, 1902), the flow on to the filter was still further increased by opening the valves to their full extent; this raised the flow to something like 75 gallons per cube yard per

* Possibly slightly under-estimated.

24 hours. During this time the distribution pipes had to be cleaned out four times a week and the effluent flint tank once a week, thus greatly increasing the labour required at the works.

Two samples of unsettled and two of final effluent were examined during the first experiment, and one of each during the second, with the following results :—

Parts per 100,000	Unsettled Effluents.			Final Effluents.		
	Expt. (*a*).		Expt. (*b*).	Expt. (*a*).		Expt. (*b*).
	No. 40.	No. 42.	No. 44.	No. 41.	No. 43.	No. 45.
	Drawn Mon. May 26th, 1902. 12.50 noon. Analysed May 27th.	Drawn Tuesday June 3rd. 12.15 noon. Analysed June 4th.	Drawn June 23rd. Analysed June 24th.	Drawn Mon. May 26th, 1902. 1.45 p.m. Analysed May 27th.	Drawn Tues. June 3rd, 1902. 12.20 noon. Analysed June 4th.	Drawn Mon. June 23rd, 1902. Analysed June 24th.
Ammoniacal Nitrogen - - -	9·37	6·21	10·23	9·71 †	6·42	9·88
Albuminoid Nitrogen - - -	0·57	0·79	0·79	0·40 †	0·42	0·65
Nitrous Nitrogen - - -	0·98	0·82	1·01	0·63	0·72	0·96
*Nitric Nitrogen - - -	4·94	4·61	4·10	4·68	3·80	3·94
Total Nitrogen - - - -	16·23	12·38	15·93	15·85	12·19	15·54
"Oxygen absorbed" at 27° C *at once*	2·34	2·04	3·05	1·89	1·83	2·78
" " " *in* 4 *hours*	7·40	6·64	7·40	5·48	4·76	7·56
Incubator Test (Scudder) - -	Slightly—	+	+	Pract. +	+	+
Incubator Test (by smell) - -	+	+	+	+	+	+
Smell when drawn - - -				+		
Smell when analysed - - -	+	+	+	+	+	+
Chlorine - - - - - -	10·70	7·92	10·70	10·40	6·90	10·32
Solids in Suspension - -	7·20	5·80	7·80	1·70	0·80	8·50
Solids by Centrifuge (vols.) - -	91·0	84·0	93·0	40·0	20·0	105·0
Ratio of Solids in Suspension to Centrifuge Solids - - -	1 : 12·6	1 : 14·5	1 : 11·9	1 : 23·5	1 : 25·0	1 : 12·4

All these effluents were brown or yellow in colour (the colour deeper than before the extra flow) and turbid from more or less suspended matter, but they all had a clean smell when analysed and probably also when drawn (this was only noted in one case). These experimental effluents were as well nitrated as the last three of the ordinary chance samples of final effluent, and they all withstood incubation. There was a distinct rise in the figures for suspended solids and for "oxygen absorbed" from permanganate in the three unsettled effluents, and this was also very marked in the last sample of final effluent. Bacteriologically, the effluent showed some signs of deterioration during the first experiment, but not to the extent that might have been anticipated. In the second experiment the bacteriological results were no longer good.

* The figures for Nitric Nitrogen are only to be taken as correct to within one or two tenths of a part.
† Done on May 29th.

NOTES ON VARIOUS SLUDGES COLLECTED AT CATERHAM.

Sludge from Cultivation Tank, Drawn June 3rd, 1902.					
No. **1**. Taken from Side Valve, 15 minutes after Valve was opened.	No. **2**. From Side Valve, 22 minutes after Valve was opened.	No. **3**. From Low Valve, 3 minutes after Valve was opened.	No. **4**. From Low Valve, 17 minutes after Valve was opened.	No. **5**. Unsettled Effluent Solids. Drawn April 29th, 1902.	No. **6**. Sludge from No. **2** Flint Tank, through which the Unsettled Effluent is strained. Drawn April 30th, 1902.
This contained very coarse solids, with fibre up to **1·5** m.m. in length. It was fermenting rapidly.	The solids in this averaged about **0·52** m.m. in length, with fibre up to about **1** m.m. This sludge seemed less putrefactive than No. **1**.	This sample was black and well disintegrated; it had a disagreeable smell. Solids up to **2** m.m. in length; fibre up to **2·3** m.m.	Solids up to **2·4** m.m.; fibre up to **0·6** m.m.	This was found to contain much flocculent matter, some coke, and a little grit. In the circular vegetable masses the microscope showed some protozoa and other organisms. The solids were putrescible in the wet state, developing an odour like that of hippuric acid.	This was dark brown in colour and very finely divided, with many small worms. The greater part of it appeared under the microscope to consist of circular light brown vegetable masses, with grit and coke in small quantity. The animalculæ were abundant and of varied species; they were more highly organised than in No. **5**.
		Analysis of the Dried Sludges.			
Nitrogen - **3·46** per cent.	Nitrogen - **2·76** per cent.	Nitrogen - **3·17** per cent.	Nitrogen - **4·36** per cent.	Nitrogen - - - **5·95** per cent. Cellulose and Coke (a good deal of coke) **18·06** „ Grit - - - - - **14·94** „	Nitrogen - - - **3·26** per cent.

Gas Evolution Experiment.

On June 15th a portion of the residues of the mixed sludges **3** and **4**, which had been standing for 10 days in bottles mostly full of air, and which had of course been decomposing, were taken for a rough Quantitative Estimation of the gas which would be evolved under (practically) anaerobic conditions.

About 10 grms. of the wet sludge were placed in a bottle along with 346 c.c. of distilled water, and the evolved gas was collected in fractions over mercury. For two months gas continued to be given off at a very considerable rate, but after that much less rapidly. The total amount evolved has probably not exceeded **70** to **80** c.c. Though the experiment is not yet concluded (in the sense that the gas fractions have not been worked up), this result shows that the portion of the sludge tested in this way had already undergone considerable fermentation in the cultivation tank.

Degree of Nitrification in the Effluents from the various filter trays.—A single experiment, carried out for the purpose of ascertaining the degree of nitrification in the effluents from the various filter trays at Caterham, was made in April **1902**. It lasted two days, and consisted in simply collecting samples of the liquid falling from each successive filter tray by means of a specially constructed shallow scoop one foot in diameter, which was placed under the centre of each tray and left there for twenty minutes. When the scoop was withdrawn, the liquid which had collected in it was immediately analysed for nitric and nitrous nitrogen, part of each sample being despatched at the same time for bacteriological analysis the next day.

The estimations gave the following figures :—

——		Nitrate Nitrogen in parts per 100,000.	Nitrite Nitrogen in parts per 100,000.
Tray No. 1 (Top)	2 p.m., 29/4/02.	1·4	0·78
„ „ 2	2.30 p.m., 29/4/02.	2·0	1·17
„ „ 3	3.30 p.m., 30/4/02.	2·25	0·93
„ „ 4	4 p.m., 30/4/02.	2·5	1·05
„ „ 5	4.30 p.m., 30/4/02.	2·5	1·17
„ „ 6	5 p.m., 30/4/02.	3·5	0·62
„ „ 7 (bottom)	6 p.m., 30/4/02.	5·5	1·05

The bacteriological analysis gave the following results :—

The Nitroso bacteria were very numerous in the effluents from trays **4**, **5**, **6** and **7**. Further, the washings from the coke taken from the bottom tray of a second filter (filter A) also contained Nitrite-producing bacteria in great abundance.

Although the conditions of experiment were not strictly comparative, the result shows clearly that nitrification commenced in the Caterham Barracks filters in the uppermost tray, and the chemical results may, therefore, be used as an argument against complete acceptance, without further experimental proof, of the Zone theory of bacterial action in filters.

SUMMARY.

The sewage from the Caterham barracks is exceptionally strong, about twice as strong as an average sewage in ammonia and in oxidizable matter as measured by the **4** hours "oxygen absorbed" test, but in the matter of suspended solids it is only slightly above the average. The great strength is due to its being a barracks sewage, to the low consumption of water per head, to the latrine system, and to the fact of very little subsoil water gaining access to the sewers.

The flow of sewage during the day is subject to extreme variations, a result of the small total volume of sewage, combined with the steep gradient of the main sewer and the latrine system, ; at night the flow is very small. Since the sewerage system receives the roof water, the volume increases largely while rain is actually falling.

The provision for grit settlement is good, provided the grit channel is emptied frequently. On the present system, however, of only cleaning it out very occasionally, large quantities of grit and other suspended solids find their way into the septic tank. Owing to the fresh condition of the sewage, the grit channel becomes filled very quickly. In such a case it is desirable that the construction should allow of a grit tank or channel being emptied easily and rapidly, otherwise the capacity of the septic tank suffers. At Caterham the emptying has to be done by manual labour, which is necessarily slow.

The valve of the primary septic tank (which is 9 feet 6 inches deep) is only 2 feet from the top, and the capacity of the tank relatively to the flow of sewage is very small, owing to the practically permanent accumulation of very dense sludge below the 2-foot level. The result is that very little settlement of suspended solids takes place in the primary tank.

In regard to the "cultivation" tank, which is filled with flints, there can be no doubt as to the highly septic condition of the liquid which emerges from it. On the other hand, it effects a very poor settlement of the suspended solids of the sewage, partly because its capacity is reduced by the flints, but mainly because it rapidly becomes clogged and the liquor then takes short cuts through it. The hourly samples of this tank liquor which passed on to the field contained 25 parts of suspended solids, and the hourly samples of the tank liquor treated on the filters 12·6 parts. The cultivation tank is sludged at intervals of about three months, by opening the valve at the bottom and allowing the sludge to flow on to the land, but this does not of course clear out all the solid matter.

Two-thirds of the liquor from the cultivation tank is passed directly on to the land. The remaining third, which is treated on the filters, though containing much less suspended matter than the field tank liquor, still has a great deal, and the liquor itself is an abnormally strong one, especially as regards ammonia. It also contains a very large number of bacteria.

The intermittent distribution on to the filters is very good, the average length of time between two discharges being twenty minutes. The small holes in the distributing pipes are, however, very apt to clog, and they require thorough brushing and pricking out at least twice a week. Less labour would of course be wanted here if a better clarified liquid were being dealt with. This method of distribution has the advantage of being practically independent of the rate of flow.

The filters are unique and their action is of great interest from a theoretical as well as from a practical point of view. Each filter consist of seven trays, which are filled with coke of different sizes, the aggregate thickness of the filtering medium being only five feet; between every two trays there is an air space, this construction ensuring a very thorough aeration of the liquid to be purified. The good aeration is evidenced by the high degree of nitration of the resulting effluent, the oxidizing process being carried out in such a way that there is only a comparatively slight actual loss of the nitrogen of the tank liquor as gaseous nitrogen.* The determinations made, on the spot, of the amounts of nitrite and nitrate in the fractional effluents examined from the various trays, showed that the process of nitrate formation began in the first tray and continued as the liquid descended.† Each of the tray filtrates was found to contain a very considerable quantity of nitrite, and the fact that the final tray effluent had as much as about one part per 100,000 of nitrous nitrogen in solution showed that nitrite was being produced faster than it could be completely oxidized by the nitro-bacteria present. The oxidation was thus not carried to its extreme, mainly because of the great ammoniacal strength of the liquid. This was in fact found to be more or less the case in all the effluents examined from Caterham.

As regards their character, the unsettled and the final effluents may be considered together, practically the only difference between them being the presence of some very flocculent suspended matter (probably averaging about 4 parts per 100,000) in the former. This matter is well removed by the effluent flint tank, the final effluent being very free from matter in suspension. These effluents were marked by their high degree of nitration. They were inoffensive as regards smell and they always contained—even the later experimental samples—much more than sufficient nitrate to prevent putrescence upon incubation. In this respect, therefore, they were satisfactory. But, on the other hand, they were capable of taking up considerable quantities of dissolved oxygen from water, though this absorption was no doubt mainly due to the suspended solids which they contained. Taken all over, they may be termed effluents of fair quality.

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* This raises a point of great interest. The presence of the large quantities of nitrite which are found in the Caterham effluents tends to throw doubt on the theory that the loss of nitrogen from biological filters, as gaseous nitrogen, is due to the formation and subsequent decomposition of ammonium nitrite into nitrogen and water.

†—cf. Rideal, *loc. cit.*

The analyses show that the oxidation had not been carried quite far enough to produce an effluent of high class ; but, in offering this criticism, the fact has to be borne in mind that the septic tank liquor treated is one of exceptional strength. The results obtained by the filtration of this liquid through an aggregate thickness of only **5** feet of filtering material could only be achieved by very efficient distribution and aeration. On a percentage basis of comparison with the tank liquor and the sewage, the effluents (unsettled and final) were remarkably good bacteriologically, but they still contained a large number of intestinal microbes.

The strength and character of the sewage at Caterham barracks is such as to render it peculiarly liable to give rise to nuisance. At the sewage outfall there is practically always some smell, but very little from either the covered grit channel or the cultivation tank, in the ordinary course of working. When the grit channel is cleaned out, however, the smell is very offensive indeed, and the same applies to the sludging of the cultivation tank, and—in a lesser degree—to the sludging of the septic tank. There are, however, no houses in the vicinity. No nuisance is produced by the sludging of the effluent flint tank.

We should like, in conclusion, to express our thanks to Mr. M. Tampling, who has charge of the installation, for all the help which he has given us in connection with our work at Caterham.

ROYAL COMMISSION ON SEWAGE DISPOSAL.

APPENDIX B.

CATERHAM

Results of the Bacteriological Examination of :—

CRUDE SEWAGE.

TANK LIQUOR.

SEMI-FINAL (*i.e.* unsettled) EFFLUENT.

FINAL EFFLUENT.

EFFLUENTS FROM THE VARIOUS TRAYS.

SLUDGE.

CONTENTS.

A. C. HOUSTON.

CATERHAM BARRACKS.

RESULTS of the Bacteriological Examination of Caterham Crude Sewage, Tank Liquor, and Effluents.

1						2																			
Description of the Sample.						Bile Salt Broth Test. A. = Acid ; G. = Gas.						Lactose Peptone Milk Test. A. = Acid ; C. = Clot ; G. = Gas.						Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method).						Chief ... ters of Coli numb...	
No.	Time of Collection.				Other Details.																			Gas.	I
	Hour.	Day.	Month.	Year.		1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	Gelatine "shake" cultures, 24 hrs. at 20° C.)	
						1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c	·001 c.c.	·0001 c.c.	·00001 c.c.		
I.	1 p.m. to 12 noon.	14–16	4	1902	*Caterham.*—Sewage every hour and according to flow.					A.G. +	—						A.G.C. +								
I.	1 p.m. to 12 noon.	16–18	,,	,,	*Caterham Barracks.*—Crude sewage every hour and according to rate of flow.						A.G. +						A.G.C. +								
I.	1 p.m. to 12 noon.	18–20	,,	,,	*Caterham Barracks.*—Crude sewage, sample every hour and according to flow. Complete.						A G. +														
I.	1 p.m. to 12 noon.	20–21	,,	,,	*Caterham Barracks.*—Crude sewage, every hour and according to flow.						A.G. +														
		19	12	,,	*Caterham.*—Tank liquor.**																		+		
B.	1 p.m. -	22	4	,,	*Caterham.*—Tank liquor as it goes on to filter.																				
C.	1·15 p.m.	,,	,,	,,	*Caterham*—Overflow from tank very foul.																				
II.	1 p.m. to 12 noon.	14–16	,,	,,	*Caterham.*—Tank liquor, equal quantities every hour.						A.G. +						A.G.C. +								
III.	1 p.m. to 12 noon.	,,	,,	,,	*Caterham.* — Tank liquor, every hour and according to flow of sewage.						A.G. +						A.G.C. +								
II.*	1 p.m. to 12 noon.	16–18	,,	,,	*Caterham Barracks.*—Tank liquor going on to filter, equal quantities every hour.						A.G. +						A.G.C. +								
II.	1 p.m. to 12 noon.	,,	,,	,,	*Caterham Barracks.*—Tank liquor going on to field, every hour and according to rate of flow of sewage.						A.G. +						A.G.C +								
I.¶	1p.m. to 12 noon.	18–20	,,	,,	*Caterham Barracks.*—Tank liquor going into filter, equal quantities every hour.						A.G. +														
III.†	p.m. to noon.	,,	,,	,,	*Caterham Barracks.*—Tank liquor going on to field, sample every hour and according to flow of sewage.						A.G. +					A.G.C. +	—								
II.	1 p.m. to 12 noon.	20–21	,,	,,	*Caterham Barracks.*—Tank liquor (filter). every hour in equal quantities.						A.G. +														
III.	1 p.m. to 12 noon.	,,	,,	,,	*Caterham Barracks.*—Tank liquor (field), every hour and according to rate of flow.						A.G. +														
106A	11.5 a.m.	23	2	1903	*Caterham.* — Tank liquor, chance sample.						A.G. +						A.G.C. +						+	+	
65		18	1	1904	*Caterham.*—Tank liquor.																+	-		+	
7	1·10 p.m.	10	,,	1904	*Caterham.*—Semi-final effluent from trays before flint bed.																				

CATERHAM BARRACKS.

RESULTS of the Bacteriological Examination of Caterham Crude Sewage, Tank Liquor, and Effluents.

Indol Test. dol in broth cultures direct (5 days at 37° C).					B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						"Gas" Test. "Gas" production in gelatine "shake" cultures, 24 hours at 20° C.						8 Neutral-red Broth Test. Greenish-yellow fluorescence, 48 hours at 37° C.						REMARKS.
10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	1 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	
							+	−						+	−							+	
								+	−					+	−							+	
								+	−					+	−							+	
								+	−					+	−							+	
				+																			**Gelatine at 20° C. 8,100,000; **Agar at 37° C 640,000 } Microbes per c.c.
								+	−				+	−								+	
							+	−						+	−							+	
								+	−				+	−								+	
							+	−					+	−								+	
							+	−					+	−								+	II.* was an average sample, but the 3, 4 and 5 p.m. hourly samples, 16/4/02, were missing.
								+	−				+	−								+	
							+	−					+	−								+	II.¶ was an average sample, but the 4 p.m. 18th to 7 a.m. 19th (inclusive) hourly samples were missing.
								+	−				+	−								+	III.† hourly samples, 4 p.m. 18th to 6 a.m. 19th, missing (otherwise an average sample).
							+	−					+	−								+	
							+	−					+	−								+	
				+				+	−				24hs +	48hrs +	72 hrs. −							+	[June 3 to 23/02 Nearly three times the usual flow was being treated.]
							+	−															
							+	−					+	−							+	−	

Results of the Bacteriological Examination of Caterham Crude Sewage, Tank Liquor, and Effluents—*continu*

1						2												3							
Description of the Sample.						Bile Salt Broth Test. A. = Acid ; G. = Gas.						Lactose Peptone Milk Test. A. = Acid ; C. = Clot ; G. = Gas.						Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method).						Chief Bio ters of t Coli pr number	
No.	Time of Collection.				Other Details.																			Gas.	Ind
	Hour.	Day.	Month.	Year.		1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	(Gelatine "shake" cultures, 24 hrs. at 20° C.)	(Broth cultures
IV.	1 p.m. to 12 noon.	14-16	4	1902	*Caterham.*—Semi-final effluent, equal quantities every hour.				A.G. +	—						A.G.C. +	—					+	—	+	+
IV.§	1 p.m. to 12 noon.	16-18	,,	,,	*Caterham Barracks.*—Semi-final effluent, equal quantities every hour.				A.G. +	—					A.G.C. +	—					+	—		+	+
IV.‖	1 p.m. to 12 noon.	18-20	,,	,,	*Caterham Barracks.*—Semi final effluent, equal quantities every hour.				A.G. +	—					A.G.C. +	—					+	—		+	+
IV.	1 p.m. to 12 noon.	20-21	,,	,,	*Caterham Barracks.*—Semi-final effluent, equal quantities every hour.				A.G. +	—											+	—		+	—
I.	3.15 p.m.	28	,,	,,	*Caterham Barracks*—Semi-final effluent, chance sample, to correspond with final.				A.G. +	—					A.G.C. +	—					+	—		+	—
IV	10.30 a.m.	29	,,	,,	*Caterham Barracks.*—Semi-final effluent, chance sample.			A.G. +	—						A.G.C. +	—				+	—			+	+
I	10 a.m.	30	,,	,,	*Caterham Barracks.*—Semi-final effluent, to correspond with final.				A.G. +	—					A.G.C. +	—						+	—	+	—
I.	10.30 a.m.	1	5	,,	*Caterham Barracks.*—Semi-final effluent, chance sample.				A.G. +	—				AGC. +	—						+	—		+	+
I.	12.50 p.m.	26	,,	,,	*Caterham*—Semi-final effluent.					A.G. +	—					A.G.C. +	—					+	—	+	+
12.	12.15 noon	3	6	,,	*Caterham.*—Semi-final effluent, chance sample.					A.G. +	—						A.G.C. +						+	+	+
I	2 p.m.	23	,,	,,	*Caterham Barracks.*—Semi-final effluent, chance sample.						A.G. +						A.G.C. +						+	+	+
660		18	1	1904	*Caterham.*—Semi-final effluent.																+	—		+	—
		19	12	1901	*Caterham.*—Drainings from last flint filter.§§																+				
S	1 p.m.	10	1	1902	*Caterham.*—Final effluent after flint bed																				
A.	12·40 p.m.	22	,,	,,	*Caterham.*—Final effluent																				
V.	1 p.m. to 12 noon.	14-16	4	,,	*Caterham.*—Final effluent equal quantities every hour.			A.G. +	—					AGC. +	—						+	—		+	+
V.	1 p.m. to 12 noon.	,,	,,	,,	*Caterham Barracks.*—Final effluent, equal quantities hourly.				A.G. +	—					A.G.C. +	—					+	—		+	+
V.	1 p.m. to 12 noon.	20-21	,,	,,	*Caterham Barracks.*—Final effluent, equal quantities every hour.				A.G. +	—										+	—			+	+
II.	5.15 p.m.	28	,,	,,	*Caterham Barracks.*—Final effluent, chance sample, corresponds with semi-final.				A.G. +	—					A.G.C. +	—					+	—		+	+
V.	10.30 a.m.	29	,,	,,	*Caterham Barracks.*—Final effluent, chance sample.				A.G. +	—				AGC. +	—							+	—	+	+
II.	11 a.m.	30	,,	,,	*Caterham Barracks*—Final effluent to correspond with semi-final, 1 hour after.				A.G. +	—					A.G.C. +	—					+	—		+	+
II.	10.30 a.m.	1	5	,,	*Caterham Barracks.*—Final effluent, chance sample				A.G. +	—				AGC. +	—						+	—		+	+

...lts of the Bacteriological Examination of Caterham Crude Sewage, Tank Liquor, and Effluents—*continued.*

Indol Test. ...l in broth cultures direct (5 days at 37° C).					B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						7 "Gas" Test. "Gas" production in gelatine "shake" cultures, 24 hours at 20° C.						8 Neutral-red Broth Test. Greenish-yellow fluorescence 48 hours at 37° C.						REMARKS.
...0 ...1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	
			+	—			+	—			+	—								+	—		
		+	—				+	—			+	—									+	—	IV.§ was an average sample, but the 3, 4 and 5 p.m. hourly samples, 16/4/02, were missing.
		+	—				+	—			+	—									+	—	IV.‖ samples, 4 p.m. 18th to 7 a.m. 19th, missing (otherwise an average sample).
		+	—				+	—			+	—								+	—		
		+	—				+	—			+	—								+	—		
	+	—					+	—			—									+	—		
		+	—				+	—			+	—								+	—		
		+	—				+	—			+	—								+	—		
			+	—			+	—				+	—									+·	Note by Dr. McGowan (June 3/02):— "For the last month the filter has been treating about double the amount of tank liquor that it did formerly." [Double flow, May 2 to June 3/02].
				+			+	—					+	—								+	
				+			+	—					+	—								+	
							+	—															
		+																					§§Gelatine at 20° C. 1,300,000 / §§Agar at 37° C. 37,000 } Microbes per c.c.
							+	—				+	—							+	—		
						+	—				+	—								+	—		
			+	—		+	—				+	—								+	—		
	+	—					+	—			+	—									+	—	V. was an average sample, but the 3 4 and 5 p.m. hourly samples, 16/4/02, were missing.
		+	—			+	—				+	—								+	—		
		+	—			+	—				+	—									+	—	
		+	—			+	—				—								+	—			
		+	—				+	—			+	—								+	—		
		+	—				+	—			—									+	—		

Results of the Bacteriological Examination of Caterham Crude Sewage, Tank Liquor, and Effluents—*continu*

1						2												3							
Description of the Sample.						Bile Salt Broth Test. A. = Acid ; G. = Gas.						Lactose Peptone Milk Test. A. = Acid ; C. = Clot ; G. = Gas.						Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method).						Chief Biol… ters of th… Coli pr… number … C…	
No.	Time of Collection.				Other Details.																			Gas.	Indo…
	Hour.	Day.	Month.	Year.		1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	(Gelatine "shake" cultures, 24 hrs. at 20° C.)	(Broth cultures, …
II.	1.45 p.m.	26	5	1902	*Caterham.*—Final effluent.				A.G. +	—						A.G.C. +	—					+	—	+	—
43.	12.20 noon	3	6	„	*Caterham.* — Final effluent, chance sample.				A.G. +	—						A.G.C. +	—				+	—		+	+
II.	2.5 p.m.	23	„	„	*Caterham Barracks.* — Final effluent, chance sample						A.G. +					A.G.C. +	—						+	+	—
3106B	11.30 a.m.	„	2	1903	*Caterham.*—Final effluent				A.G. +	—						A.G.C. +	—					+	--	+	+
661		18	1	1904	*Caterham.*—Final effluent																	+	—	+	+
I.	2 p.m.	29	4	1902	*Caterham Barracks.*—Effluent from Tray I.																				
II.	2.30 p.m.	„	„	„	*Caterham Barracks.* — Effluent from Tray II.																				
III.	3.30 p.m.	„	„	„	*Caterham Barracks.* — Effluent from Tray III.																				
III.	3 p.m.	30	„	„	*Caterham Barracks.* — Effluent from Tray No. IV.					A.G. +	—														
IV.	3.40 p.m.	„	„	„	*Caterham Barracks.* — Effluent from Tray No. V.						A.G. +														
V	4.30 p.m.	„	„	„	*Caterham Barracks.* — Effluent from Tray No. VI.				A.G +	—															
VI.	5.45 p.m.	„	„	„	*Caterham Barracks.* — Effluent from Tray No. VII.					A.G. +	—														
3. C.		3	6	1902	*Caterham.*—Sample of sludge				+ ·0001 c.c.						+ ·000001 c.c.						+ ·0000001 c.c.			+	+
4. D.		„	„	„	*Caterham.*—Sample of sludge				+ ·000001 c.c.						+ ·000001 c.c.								+	+	+
5. E.		„	„	„	*Caterham.*—Sample of sludge				+ ·0001 c.c.						+ ·0001 c.c.							+	—	+	+
6. F.		„	„	„	*Caterham.*—Sample of sludge				+ ·000001 c.c.						+ ·00001 c.c.							+	—	+	+

lts of the Bacteriological Examination of Caterham Crude Sewage, Tank Liquor, and Effluents—*continued.*

	5				6						7						8						9
	Indol Test. in broth cultures direct (5 days at 37° C).				B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						"Gas" Test. "Gas" production in gelatine "shake" cultures, 24 hours at 20° C.						Neutral-red Broth Test. Greenish-yellow fluorescence, 48 hours at 37° C.						REMARKS.
	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	
		+	—				+	—				+	—								+	—	
		+	—					+					+	—							+	—	
				+			+	—					+	—								+	
			+	—			+	—				24 +	48 +	72 +	72 +	72 —				+	—		
						+	—																
																				+	—		
																						+	
																					+	—	
+ ·0000001 c.c.								+	—				+	—					+ ·000001 c.c.				Notes by Mr. Frye. *Sludge Samples* :— No. 3. "C."—"Sample of sludge taken from side valve of primary tank, 15 minutes after valve was opened. Before putting this in sample bottle, some of the supernatant water with thin mud was poured off."
				+				+	—					+	—				+ ·000001 c.c.				No. 4. "D."—"Sample of sludge from side valve, drawn 22 minutes after valve was opened. The valve is opened about once in three months."
			+	—				+	—				+	—							+	—	No. 5. "E."—"Sample of sludge taken from the *bottom* outlet sludge valve of the flint tank (below the filters). This sample was drawn 3 minutes after the valve was opened."
			+	—					+	—			+	—					+ ·000001 c.c.				No. 6. "F."—"Sample of sludge from same source as No. 5, drawn 17 minutes after the valve was opened. This low valve is opened once in three months or so."

CATERHAM.

SUMMARY OF RESULTS.

Sewage.

4 Samples.

The bile-salt glucose peptone, lactose peptone milk, and neutral-red broth tests yielded parallel results, namely, a positive result with $\frac{1}{100000}$ c.c., except one sample, examined by the bile-salt glucose peptone test, which yielded a positive result with $\frac{1}{10000}$, but not with $\frac{1}{100000}$ c.c.

Three out of the four samples yielded a positive result with $\frac{1}{1000}$ c.c. with the B. enteritidis sporogenes test.

All four samples yielded "gas" in gelatine "shake" cultures within 24 hours at 20° C with $\frac{1}{1000}$ c.c.

Tank Liquor.

12 Samples.

Practically speaking, all the samples that were tested yielded with the bile salt glucose peptone, lactose peptone milk, and neutral red broth tests a positive result with $\frac{1}{100000}$ c.c.

As regards the B. enteritidis sporogenes test, five samples yielded a positive results with $\frac{1}{1000}$ and seven with $\frac{1}{100}$ c.c.

Ten out of eleven samples yielded a positive result with the "gas" test ("gas" in gelatine "shake" cultures within 24 hours at 20° C) with $\frac{1}{100}$ c.c.

---

* Unless otherwise stated, the results are given as number of bacteria per c.c. of sample.

N.B.—As regards the bile-salt glucose peptone, lactose peptone milk, B. coli, indol, and neutral red broth tests, it should be noted that the tests were not "pushed" beyond $\frac{1}{100000}$ c.c.

Final and Semi-final Effluents.*

28 Samples.

It is desirable to consider the results of the examination of the final and semi-final effluents together. The percentage reduction in the number of bacteria in the effluents as compared with the sewage was remarkable.

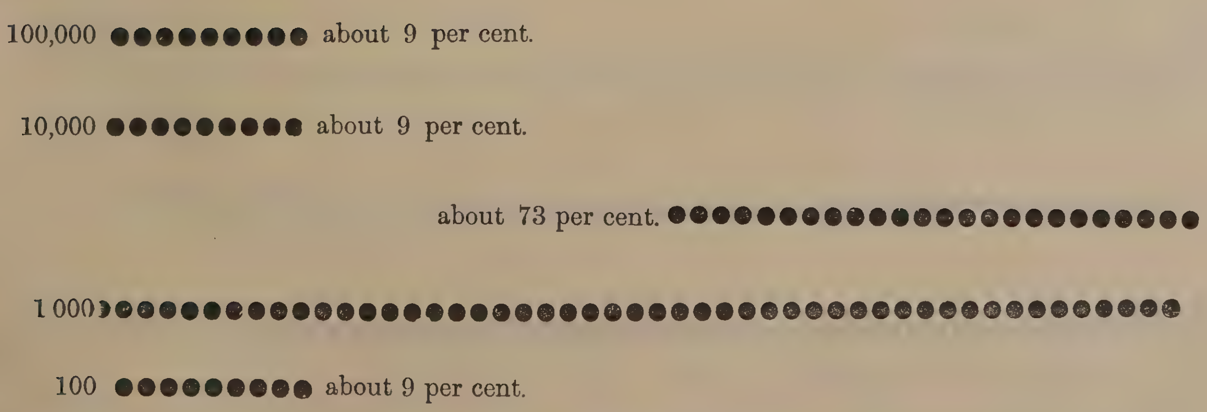
Bile-Salt Glucose Peptone Test.

22 Samples

2	samples	(about 9 per cent.)	100,000	(+ ·00001 c.c.)
2	„	(about 9 per cent.)	10,000	(+ ·0001 c.c.)
16	„	(about 73 per cent.)	1,000	(+ ·001 c.c.)
2	„	(about 9 per cent.)	100	(+ ·01 c.c.)

These results may be shown in a diagram (each dot represents 1 per cent. of the samples) as follows:—

Bile-salt glucose peptone test.



* The final and semi-final effluents are considered together because they yielded fairly comparable results.

Caterham Final and Semi-Final Effluents.

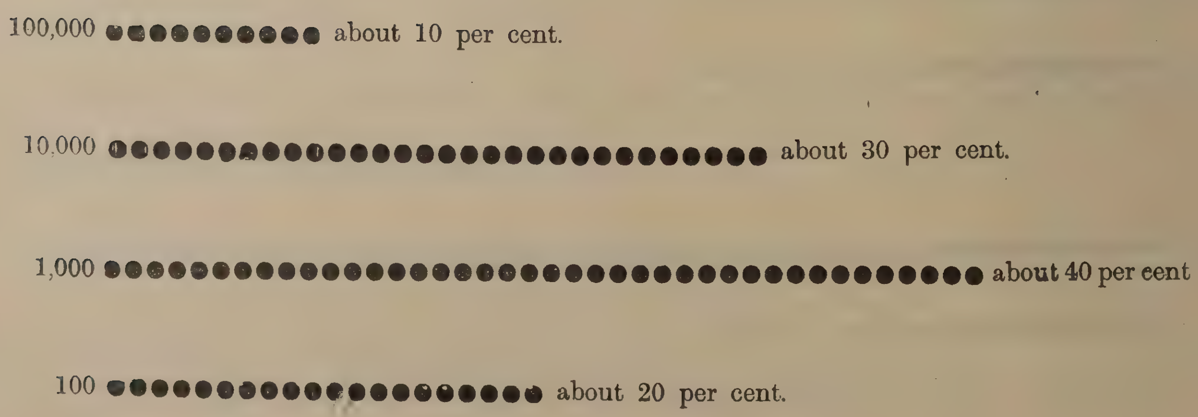
Lactose Peptone Milk Test.

20 Samples.

2 samples (about 10 per cent.)	100,000	(+	·00001 c.c.)
6 samples (about 30 per cent.)	10,000	(+	·0001 c.c.)
8 samples (about 40 per cent.)	1,000	(+	·001 c.c.)
4 samples (about 20 per cent.)	100	(+	·01 c.c.)

These results may be shown in a diagram (each dot represents one per cent. of the samples) follows:—

Lactose Peptone Milk Test



Caterham Final and Semi-final Effluents

B. Coli Test.

25 Samples.

3	samples	(about 12 per cent.)	100,000	(+ ·00001 c.c.)
7	„	(about 28 per cent.)	10,000	(+ ·0001 c.c.)
13	„	(about 52 per cent.)	1,000	(+ 001 c.c.)
2	„	(about 8 per cent.)	100	(+ ·01 c.c.)

These results may be shown in a diagram (each dot represents one per cent. of the samples), as follows:—

B. coli test.

100,000 ●●●●●●●●●●●● about 12 per cent.

10,000 ●●●●●●●●●●●●●●●●●●●●●●●●●●●● about 28 per cent.

about 52 per cent. ●●●
1,000 ●●

100 ●●●●●●●● about 8 per cent.

As regards the biological characters of the B. coli or coli-like microbes isolated from the effluents, sixteen out of twenty-four (66 per cent.) were, on the basis of the tests employed, typical B. coli.

Caterham Final and Semi-final Effluents.

Indol Test.

23 Samples

3 samples	(about 13 per cent.)	100,000	(+ ·00001 c.c.)
4 ,,	(about 17 per cent.)	10,000	(+ ·0001 c.c.)
14 ,,	(about 60 per cent.)	1,000	(+ ·001 c.c.)
2 ,,	(about 8 per cent.)	100	(+ ·01 c.c.)

These results may be shown in a diagram (each dot represents one per cent. of the samples) follows:—

Indol Test.

100,000 ●●●●●●●●●●●●● about 13 per cent.

10,000 ●●●●●●●●●●●●●●●●● 17 per cent.

about 60 per cent. ●●●●●●●●●●●●
1,000 ●●

100 ●●●●●●●● about 8 per cent.

Caterham Final and Semi-final Effluents.

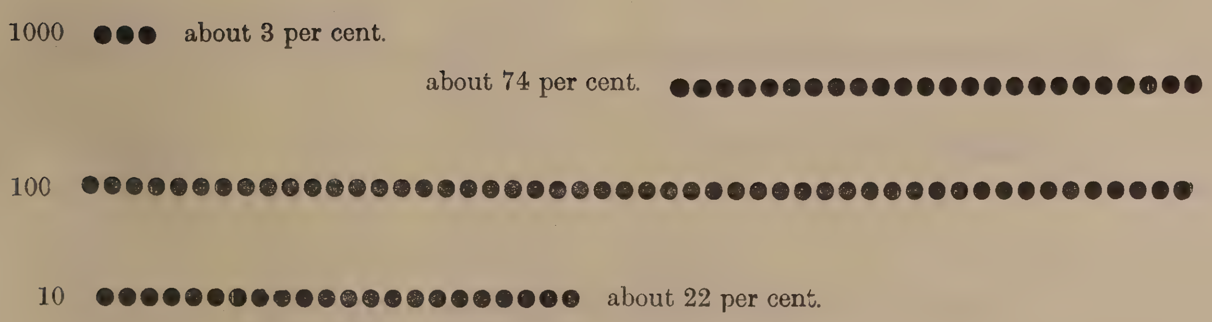
B. Enteritidis Sporogenes Test.

27 Samples.

1 sample	(about 3 per cent.)	1000	(+ ·001 c.c.)
20 „	(about 74 per cent)	100	(+ ·01 c.c.)
6 „	(about 22 per cent.)	10	(+ ·1 c.c.)

These results may be shown in a diagram (each dot represents one per cent. of the samples as follows :—

B. Enteritidis Sporogenes Test



" Gas " test (" gas " in gelatine shake cultures within 24 hours at 20° C.)

25 Samples.

About half the samples yielded a positive result with 1 c.c., but a negative result with ·1 c.c.

Caterham Final and Semi-final Effluents.

Neutral Red Broth Test.

25 Samples.

4 samples	(about 16 per cent.)	100,000	(+ ·00001 c.c.)
7 „	(about 28 per cent.)	10,000	(+ ·0001 c.c.)
13 „	(about 52 per cent.)	1,000	(+ ·001 c.c.)
1 „	(about 4 per cent.)	100	(+ ·01 c.c.)

These results may be shown in a diagram (each dot represents one per cent. of the samples) as follows:—

Neutral Red Broth Test.

100,000 ●●●●●●●●●●●●●●●● about 16 per cent.

10,000 ●●●●●●●●●●●●●●●●●●●●●●●●●●●● about 28 per cent.

●●●●●● about 52 per cent.
1,000 ●●

100 ●●●● about 4 per cent.

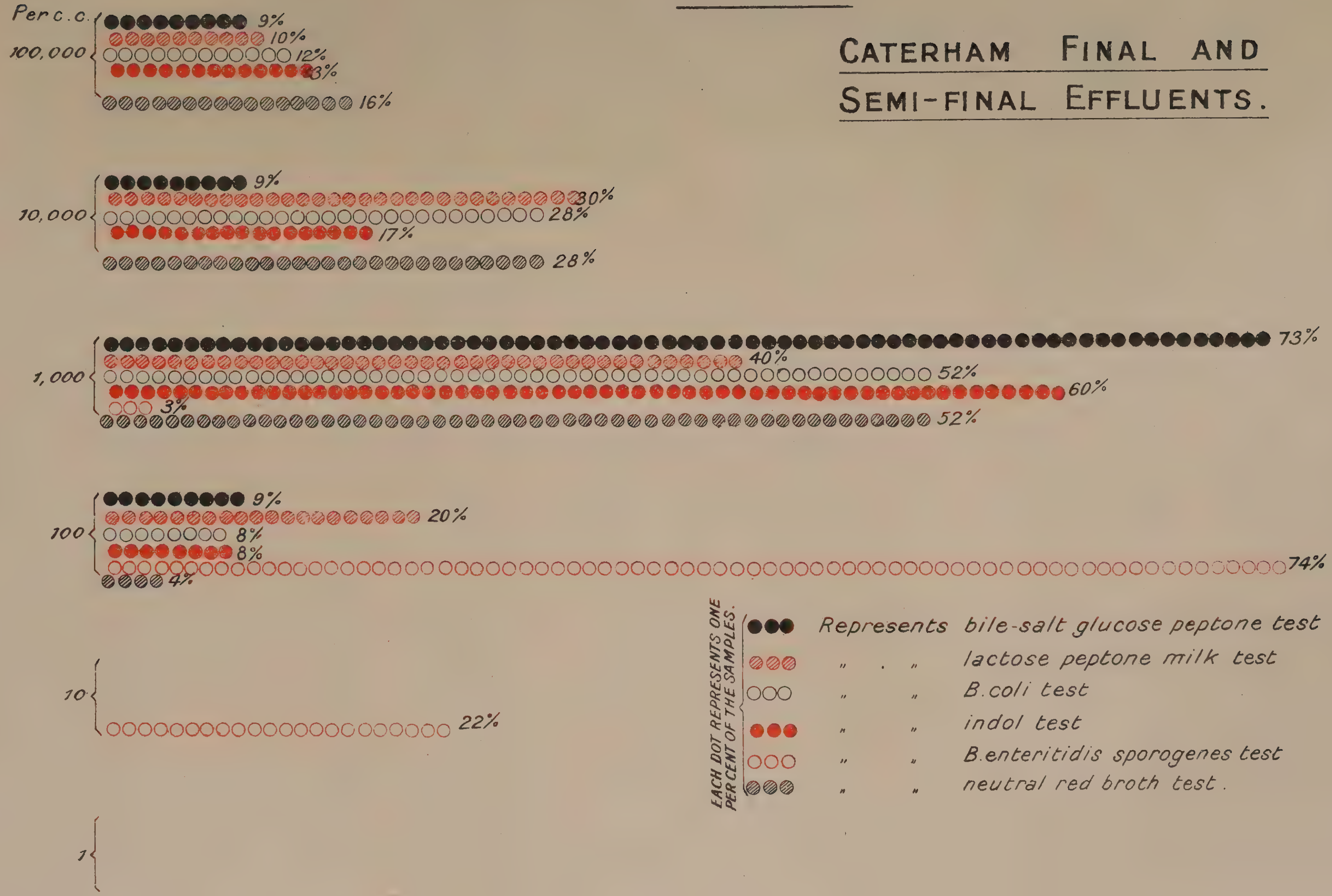
Effluents from Separate Trays and Samples of Sludge.

A few of the effluents from the separate trays, and also a few samples of sludge, were examined bacteriologically (for results, *see* General Table.)

In Diagram E. the results of the bacteriological examination of the final and semi-final effluents are brought together for comparative purposes.

Diagram E.

Caterham Final and Semi-final Effluents.



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GENERAL REMARKS.

On a percentage basis of comparison the effluents were undeniably good, bacteriologically.

Thus, whilst practically all the samples of sewage and tank liquor yielded *positive* results with ·00001 c.c. (100,000 per c.c.) with the bile-salt glucose peptone, lactose peptone milk, B. coli, indol and neutral red broth tests, the percentage number of samples of effluent yielding *negative* results with ·0001 c.c. (10,000 per c.c.) with the same tests, taken in the same order, was as follows:—82, 61, 61, 69 and 56 per cent.

As regards the B. enteritidis sporogenes test, whereas 8 out of 11 (about 76 per cent.) of the samples of sewage and tank liquor yielded positive results with ·001 c.c. (1000 per c.c.), 96 per cent. of the effluents yielded negative results with a similar quantity of liquid.

On the other hand, it must not be inferred that effluents, even where, as in the present case, they show a high percentage degree of purification, are, unless the *actual* results are likewise satisfactory, in a fit state to be discharged into *drinking* water streams.

ADDENDUM.

NUMBER OF NITRITE PRODUCING BACTERIA IN THE CATERHAM EFFLUENTS AND "WASHINGS" FROM THE COKE.

A series of tubes containing sterile ammoniacal solution* were inoculated with fractional amounts of effluent and "washings" from the coke, and tested from time to time as regards nitrite production.

The procedure was as follows:—

Experiment I., May 1st., 1902.

(*a*) Eight tubes (containing sterile ammoniacal solution) were inoculated severally with $\frac{1}{10}$, $\frac{1}{100}$, $\frac{1}{1000}$, $\frac{1}{10000}$, $\frac{1}{100000}$, $\frac{1}{1000000}$, $\frac{1}{10000000}$, and $\frac{1}{100000000}$ of a cubic centimetre of the effluent from Tray IV.

(*b*) Ditto, effluent from Tray No. V.

(*c*) Ditto, effluent from Tray No. VI.

(*d*) Ditto, effluent from Tray No. VII.

---

* Sodium carbonate, sodium phosphate, and ammonium chloride, of each 0·1 per cent.

Experiment II., May 4th, 1904.

111 grammes of coke from the bottom tray of filter A were placed in a sterile wide-mouthed stoppered bottle. 100 c.c. of sterile water were next added, and the bottle shaken for some time. After allowing the grosser particles to subside, 10 c.c. of the coke "washings" were added to 90 c.c of sterile water contained in a flask. From this flask further dilutions were made by the decimal mode of dilution. 1 c.c. from the various dilutions was added separately to tubes containing sterile ammoniacal solution. The tubes contained as the result $\frac{1}{10}$, $\frac{1}{100}$, $\frac{1}{1000}$, $\frac{1}{10000}$, $\frac{1}{100000}$, $\frac{1}{1000000}$, $\frac{1}{10000000}$, and $\frac{1}{100000000}$ of a cubic centimetre of "washings" of the coke (111 grammes coke + 100 c.c. water.)

From time to time the tubes (incubated at 20° C.) were tested in the following manner —

One c.c. was withdrawn by means of a sterile pipette, and added to 9 c.c. of distilled water. Two drops of meta-phenylene-diamine were next added. The presence of nitrite was evidenced by a Bismarck brown colouration of the liquid.

The results are shown in the following tables:—

Effluent from Tray No. IV.

(+ indicates presence of nitrite.)

Date of Testing.	$\frac{1}{10}$ c.c.	$\frac{1}{100}$ c.c.	$\frac{1}{1000}$ c.c.	$\frac{1}{10000}$ c.c.	$\frac{1}{100000}$ c.c.	$\frac{1}{1000000}$ c.c.	$\frac{1}{10000000}$ c.c.	$\frac{1}{100000000}$ c.c.
10–5–02. - - -	?	—	—	—	—	—	—	—
17–5–02. - - -	+	?	—	—	—	—	—	—
24–5–02. - - -	+	+	+	+	+	—	+	—
31–5–02. - - -	+	+	+	+	+	—	+	—
6–6–02. - - -	+	+	+	+	+	slight +	+	—
15–6–02 - - -	+	+	+	+	+	+	+	—
26–6–02 - - -	+	+	+	+	+	+	+	—

Effluent from Tray No. V.

Date of Testing.	$\frac{1}{10}$ c.c.	$\frac{1}{100}$ c.c.	$\frac{1}{1000}$ c.c.	$\frac{1}{10000}$ c.c.	$\frac{1}{100000}$ c.c.	$\frac{1}{1000000}$ c.c.	$\frac{1}{10000000}$ c.c.	$\frac{1}{100000000}$ c.c.
10–5–02 - - -	?	—	—	—	—	—	—	—
17–5–02 - - -	+	?	?	—	—	—	—	—
24–5–02 - - -	+	+	+	+	+	—	—	—
31–5–02 - - -	+	+	+	+	+	—	—	—
6–6–02 - - -	+	+	+	+	+	—	—	—
15–6–02 - - -	+	+	+	+	+	—	—	—
26–6–02 - - -	+	+	+	+	+	—	—	—

Effluent from Tray No. VI.

Date of Testing.	$\frac{1}{10}$ c.c.	$\frac{1}{100}$ c.c.	$\frac{1}{1000}$ c.c.	$\frac{1}{10000}$ c.c.	$\frac{1}{100000}$ c.c.	$\frac{1}{1000000}$ c.c.	$\frac{1}{10000000}$ c.c.	$\frac{1}{100000000}$ c.c.
10 5–02	?	—	—	—	—	—	—	—
17–5–02	+	?	?	—	—	—	—	—
24–5–02	+	+	+	+	?	—	—	—
31–5–02	+	+	+	+	?	?	—	—
6–6–02	+	+	+	+	+	+	—	—
15–6–02	+	+	+	+	+	+	?	+
26–6–02	+	+	+	+	+	+	+	+

Effluent from Tray No. VII.

Date of Testing.	$\frac{1}{10}$ c.c.	$\frac{1}{100}$ c.c.	$\frac{1}{1000}$ c.c.	$\frac{1}{10000}$ c.c.	$\frac{1}{100000}$ c.c.	$\frac{1}{1000000}$ c.c.	$\frac{1}{10000000}$ c.c.	$\frac{1}{100000000}$ c.c.
10–5 02	?	—	—	—	—	—	—	—
17–5–02	+	?	—	—	—	—	—	—
24–5–02	+	+	+	—	—	—	—	—
31–5–02	+	+	+	?	—	—	—	—
6–6–02	+	+	+	+	—	?	+	—
15–6–02	+	+	+	+	+	+	+	—
26–6–02	+	+	+	+	+	+	+	—

"Washings" from Coke.

Date of Testing.	$\frac{1}{10}$ c.c.	$\frac{1}{100}$ c.c.	$\frac{1}{1000}$ c.c.	$\frac{1}{10000}$ c.c.	$\frac{1}{100000}$ c.c.	$\frac{1}{1000000}$ c.c.	$\frac{1}{10000000}$ c.c.	$\frac{1}{100000000}$ c.c.
10–5–02	—	—	—	—	—	—	—	—
17–5–02	?	—	—	—	—	—	—	—
24–5–02	+	slight +	?	?	—	—	?	—
31–5–02	+	+	+	+	—	—	+	—
6–6–02	+	+	+	+	—	—	+	—
15–6–02	+	+	+	+	+	+	+	—
26–6–02	+	+	+	+	+	+	+	—

N.B.—The results indicate that the number of nitrite producing bacteria in the effluents from the various trays, and in "washings" from the coke, was very great.

CHORLEY SEWAGE WORKS.

(Corporation of Chorley).

1.	Situation of works	About 1 mile from Chorley.
2.	Method of treatment	Chemical precipitation and quiescent subsidence, with continuous filtration through very fine material on the intermittent flush plan.
3.	Population draining to works during observations	27,000 (estimated average).
4.	Water supply in gallons per head and whence obtained	21. From the Liverpool Corporation gathering grounds at Rivington —a fairly soft moorland water.
5.	Number of W.C.'s	6,000
6.	Sewerage system	Combined.
7.	Average dry weather flow of sewage in gallons per 24 hours	900,000
8.	Gallons of sewage per head per day	33
9.	Character of the sewage	Domestic sewage of average strength. *
10.	Period of observations	November, 1902 to December, 1904.
11.	Age of filters	About 7 years.
12.	Amount of storm water treated on filters during observations	About twice the dry weather flow.
13.	Total capacity of tanks in gallons	1,120,000
14.	Total area of filters in yards super	2,127
15.	Total cubic content of filters in yards cube	2,127
16.	Nature of filtering material	Gravel, polarite and sand.
17.	Gallons of tank liquor treated per yard super for 24 hours (all filters included)	525
18.	Gallons of tank liquor treated per yard cube per 24 hours	525
19.	The final effluent is discharged into	The River Yarrow, a river somewhat polluted by discharges from manufactories, which joins the Douglas and flows with it to the Ribble.

* In dry weather the sewage consists of the discharge from about 6,000 water closets, small quantities of liquor from a gas works, some condenser water from cotton mills, a fair quantity of subsoil water, and also the waters of a small stream called the Chor. In wet weather large quantities of road and brook water enter the sewers.

FLOW OF SEWAGE.

The access of roof and road water and also of the water of the river Chor to the sewers during rain results in their carrying large quantities of storm water at such times. The system is constructed to carry six dilutions to the works, but although this quantity arrives there in times of rain, the setting of the works storm over-flow results in the treatment, during ordinary wet weather, of not more than three times the dry weather flow at the outside. There are three storm over-flows on the system, one in the town and two on the main outfall sewer. Of the latter, one is situated just in front of the inverted syphons and the other at the outfall. The

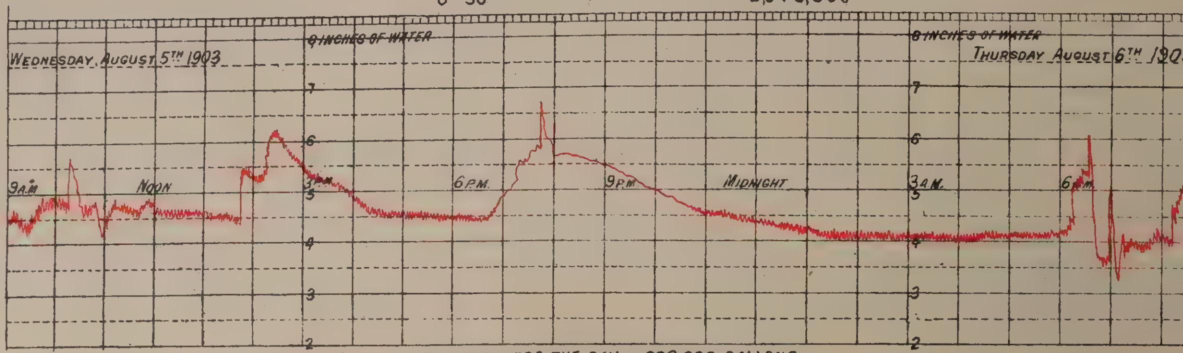
Diagram F.

DIAGRAMS SHOWING FLOW OF SEWAGE AT CHORLEY.

AS FALLING OVER A WEIR 24" WIDE.

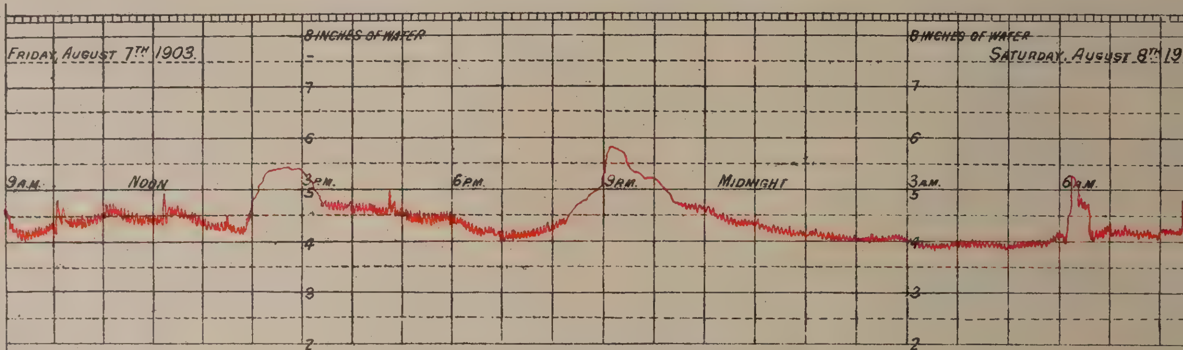
Note:- Over a Weir 24" wide				
3·75 inches	=	a rate of	603,360	gallons per 24 hours.
5·00 "	=	" " "	933,120	" " " "
6·00 "	=	" " "	1,226,880	" " " "
7·00 "	=	" " "	1,548,000	" " " "
8·00 "	=	" " "	1,886,400	" " " "
8·50 "	=	" " "	2,073,600	" " " "

DRY DAY.
RAINFALL NIL.



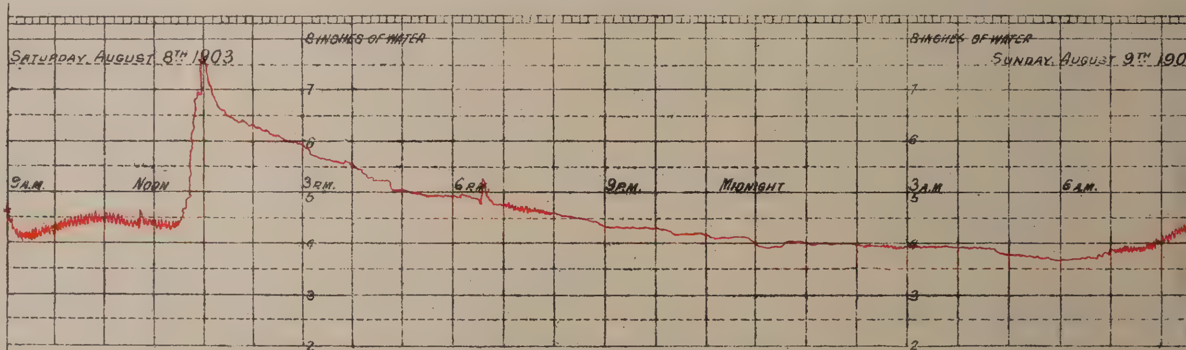
TOTAL FLOW FOR THE DAY = 932,300 GALLONS.

DRY DAY.
RAINFALL NIL.



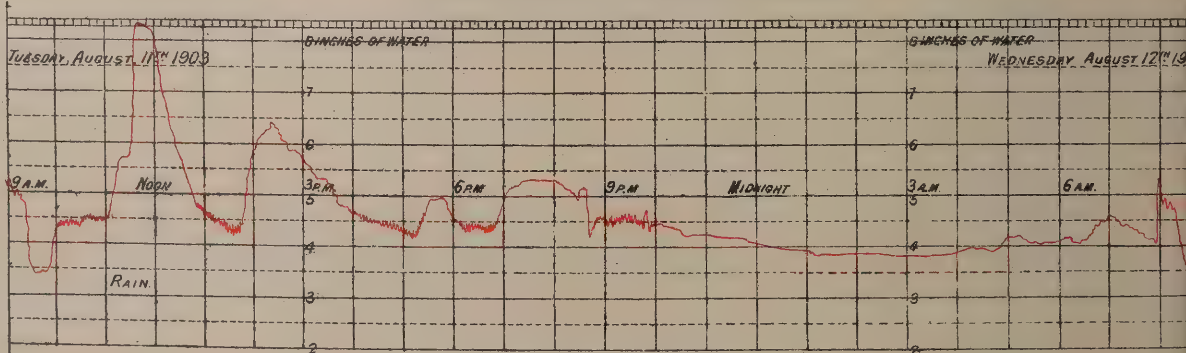
TOTAL FLOW FOR THE DAY = 863,800 GALLONS.

DRY DAY.
RAINFALL NIL.



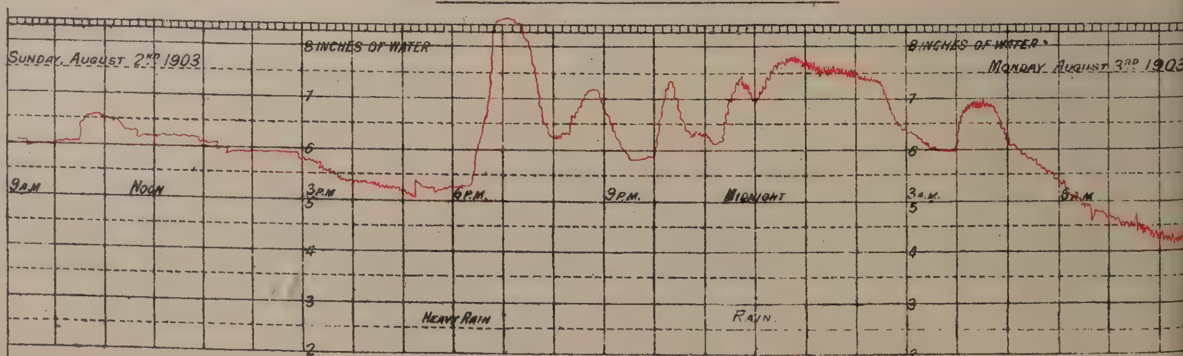
TOTAL FLOW FOR THE DAY = 896,190 GALLONS

SHOWERY DAY.
RAINFALL
0·025 INCH.



TOTAL FLOW FOR THE DAY = 900,600 GALLONS.

WET DAY.
RAINFALL
0·49 INCH.



TOTAL FLOW FOR THE DAY = 1,403,250 GALLONS

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overflow placed close to the syphons carries any flow exceeding six dilutions to the original bed of the Chor, which also receives the storm water discharging from the town overflow. The works overflow is set lower than this.

As will be seen below, we estimate the dry weather flow of sewage during 1903–4 to have been 900,000 gallons per day. From daily records of the quantities actually treated in the tanks during those years, the average amount was approximately 1,131,000 gallons per day. On the whole period, therefore, the increase of flow at the Chorley works due to rain was about 231,000 gallons per day, or25 per cent. of the dry weather flow. The greatest amount of sewage treated in one month during 1903–4 was an average of 2,071,000 gallons per day in February, 1904, or a quantity exceeding twice the dry weather flow for 28 days The smallest quantity of sewage treated per month during the same years was an average of 930,000 gallons per day, In July, 1904.

From July 26th, 1903, to May 31st, 1905, the storm overflow at the cemetery came into operation on 65 days and the works storm overflow on 189 days.

Our flow measurements at Chorley were made in July and August, 1903. They extended over a period of three weeks. In a practically dry week during these measurements we found the average daily flow to be approximately 896,000 gallons per 24 hours, and, allowing for a slight increase in the flow during 1904 because of the increase in the population, we estimate that the average dry weather flow to the Chorley works during our observations was approximately 900,000 gallons per day. If the sewage flow had been equivalent to the water supply alone, it would have amounted to only 567,000 gallons per day. In the dry week, just mentioned, the highest day's flow of 932,000 gallons occurred on the Wednesday, and the lowest day's flow of 853,000 gallons on the Thursday. Owing probably to the influx of the river Chor and of a considerable quantity of subsoil water, the sewage flow is of an even character. On five of the days in the dry week the variations were gradual from about one volume during the night to two volumes at two definite periods in the day, at about 2 p.m. and 7 or 8 p.m. On the Wednesday, which is slaughtering day, the fluctuations were rather more marked ; and on the Sunday, at about one p.m., the greatest variation in flow of the week occurred. The average amount of sewage flowing to the tanks for treatment during the years 1903-4 was 1,131,000 gallons.

On Diagram F. are given some illustrations of the sewage flow at Chorley.

Crude Sewage.—Six samples in all were examined chemically, viz., four hourly sets of 24 hours each, drawn according to rate of flow, one ordinary chance sample, and one sample of weakest night sewage. While the first 24 hours' sample, No. 3,201A, was being drawn, in July, 1903, 0·31 inch of rain fell, and further sampling was postponed for a fortnight. This sample, although marked at the time as being rather dilute, did not differ very materially from the other three sets of hourly samples, Nos. 3211A, 3214A and 3217A, drawn in August 1903, and it is therefore included with them here. The following figures were obtained :—

Parts per 100,000		Average.	Number of Estimations.	No. 3204. Weakest Night Sewage.
Ammoniacal Nitrogen	(3·24 to 4·43)	3·96	(4)	1·17
Albuminoid Nitrogen	(0·90 to 1·07)	0·99	(4)	0·12
Total Organic Nitrogen	(1·60 to 2·09)	1·91	(3)	
Oxidised Nitrogen		0·0	(4)	0·07
Total Nitrogen	(5·78 to 6·46)	6·11	(3)	0·88 (?)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(2·90 to 3·51)	3·09	(4)	0·61
" " " " *in 4 hours*	(11·42 to 13·99)	12·22	(4)	1·41
Chlorine	(7·26 to 9·88)	8·69	(4)	
Solids in Suspension	(22·6 to 46·5)	31·10	(4)	6·2
Solids by Centrifuge (volumes)	(129·0 to 286·0)	192·0	(4)	15·0
Ratio of Solids in Suspension to Centrifuge Solids	(1 : 4·3 to 1 : 8·2)	1 : 6·4	(4)	1 : 2·5

A small quantity of rain fell during the three days when the second sets of hourly samples were being taken, viz., 0·18″, 0·03″, and 0·0″; so, upon the whole, the above hourly samples are probably *slightly* weaker than a true average for the month of August. On the other hand, the comparatively large quantity of suspended matter in No. 3211A indicates that the rain had washed some solids out of the sewers. All the sets of hourly samples were noted, on analysis, as having a sour sewage smell.

The sewage is one of about average strength.

No. 3204, the sample of weak night sewage, was probably also diluted a little by the rain of the preceding day. It had a slight sewage smell when drawn, but only a faint earthy one when it came to be analysed, and hence must have originally contained a little nitrate derived from subsoil water.

The remaining chance sample of sewage, No. 3087, drawn in January, 1903, at 7.30 p.m., was only about two-thirds of the strength of the hourly samples.

Storm Water.—No. 3261 represents a sample of storm overflow discharge, drawn at 3.10 p.m. on October 13th, 1903, after the storm overflow had been working for 15 hours. It contained 1·82 parts total nitrogen and 10·2 parts of rather flocculent (and therefore, no doubt, sewage) solids, while the two "oxygen absorbed" figures were 1·22 and 5·52. The sample had a soapy smell when it came to be analysed, and became putrid and blackened on incubation. It would have been well had those solids been settled out before the liquid was discharged.

Bacteriological Notes.—As only one sample of crude sewage was examined bacteriologically, the results are included in the table dealing with precipitation liquor given in a later part of this report. It yielded positive results with 1/100,000 c.c. and 1/100 c.c. with the neutral red broth and B. enteritidis sporogenes tests, respectively.

SCREENS AND DETRITUS TANKS.

Immediately on its arrival at the works, after passing the works storm overflow, the sewage passes through the single detritus tank,* which measures 42 feet by 4 feet and 4 feet deep, and has a capacity of 4,200 gallons. The matter deposited in this tank consists chiefly of grit, especially in times of storm. It has been removed once a week during our observations by means of a chain pump, and given, with the screenings, to the tenant of the Corporation farm. From this tank the sewage passes a half-inch screen,* raked automatically by a water wheel, on its way to the precipitation tanks.

PRECIPITATION TANKS.

Number - - - -	8.
Size of each - - - -	90 feet by 48 feet.
Average depth - -	5 feet 3 inches.
Capacity of each - - -	140,000 gallons.
Total capacity - - -	1,120,000 gallons.
Construction - - -	Brick and cement, with a concrete bottom sloping towards the outlet end.

Precipitant.—Sulphate of Alumina in various trade forms was formerly used; but a precipitant of a similar kind is now made at the works and has been in use during our observations. It is made by treating Bauxite with fairly strong crude sulphuric acid, and allowing the mixture to cool in moulds. It is put into the sewage channel in the form of blocks. The average amount of precipitant used during 1903-4 was 13cwt. 8lbs. per day, equivalent to about nine grains per gallon of sewage.

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* The tank and screen have now been constructed in duplicate.

Working.—The tanks are filled in rotation. When full, they are allowed to rest until the liquid standing in them is judged to be sufficiently clear to filter, and the supernatant liquid is then drawn off by means of floating arms. In dry weather the period of rest in the tanks varies from two to four hours. In wet weather the precipitated sewage settles more rapidly, and then, as a rule, it is not necessary to retain the liquid in the tanks for more than one hour. The sludge lying at the bottom of a tank is usually removed after the tank has been filled twice.

Sludging.—After drawing off the supernatant liquid from a tank which contains enough sludge to necessitate its cleaning out, the sludge is allowed to gravitate to a sump and the tank is thoroughly cleaned out with squeegees. From the sump the sludge is raised by means of compressed air, lime being added at the same time to the sludge presses, and the mixture is then pressed into cake. The average amount of pressed cake produced per day during 1903-4 was 7 tons 12 cwt. 14lbs., and the average amount of lime used to produce this amount was 6cwt. 3qrs. 25lbs. The press water, which is very strongly alkaline with lime, passes back to the tanks. There has been no difficulty at Chorley in disposing of the pressed cake, for the neighbouring farmers take it practically all the year round, chiefly for use upon grass land. The Corporation originally charged them 1/- per load, but the demand has lately been great enough to raise the price to 1/6.

Precipitation Liquor.—Four sets of hourly samples and six chance samples of precipitation liquor were examined chemically, the hourly sets—Nos. 3202B, 3212B, 3215B and 3218B—being drawn in equal quantities every hour, at the same times and under the same conditions as the four sets of hourly sewage samples. They gave the following figures on analysis ;

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(3·10 to 3·87)	3·64	(4)
Albuminoid Nitrogen	(0·52 to 0·65)	0·57	(4)
Total Organic Nitrogen	(0·82 to 0·96)	0·88	(3)
Total Nitrogen	(4·62 to 4·83)	4·70	(3)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(0·92 to 1·24)	0·98	(4)
" " " " *in 4 hours*	(3·95 to 5·20)	4·86	(4)
Chlorine	(7·50 to 10·74)	9·22	(4)
Solids in Suspension	(2·25 to 3·40)	2·89	(4)
Solids by Centrifuge (volumes)	(24·0 to 37·0)	30·8	(4)
Ratio of Solids in Suspension to Centrifuge Solids	(1 : 8·8 to 1 : 13·8)	1 : 10·8	(4)

These sets of hourly samples, which had for the most part a somewhat sour smell when analysed, were thus wonderfully even in composition. They show that the precipitation effected at Chorley is excellent, and that the filters were, at that time, only dealing with a liquor of very moderate strength, on the average. As compared with the four sets of hourly sewage samples, we have the following reduction figures :

Calculated on :—	Reduction.
Albuminoid Nitrogen	42 per cent.
Total Organic Nitrogen	54 "
"Oxygen Absorbed" *at once*	68 "
" " *in 4 hours*	60 "
Solids in Suspension	91 "

The six chance samples examined chemically were Nos. 3045, 3088A, 487, 3192, 3331, 3407 and 3474. These were taken at all times of the year, in dry and in wet weather, and at hours varying between 10.30 a.m. and 8.15 p.m. As was therefore to be expected, they varied greatly in strength, hence too much importance must not be attached to the average of their figures. The following results, among others, were obtained :—

	Parts per 100,000.	Average.	Number of Estimations.
Total Nitrogen - - - - - - - - - -	(1·28 to 8·85)	4·97	(4)
"Oxygen absorbed" at 27°C. (80° F.) *at once* - - - -	(0·39 to 1·93)	1·10	(6)
" " " " *in 4 hours* - - -	(1 69 to 14·37)	5·50	(7)
Solids in Suspension - - - - - - - -	(1·84 to 2·66)	2·14	(3)
Solids by Centrifuge (Vols.) - - - - - - -	(6·3 to 33·0)	15· 3	(7)
Ratio of Solids in Suspension to Centrifuge Solids - -	(1 : 4·0 to 1 : 12·4)	1 : 8·2	(3)

In one point all these samples were alike, viz., in their comparative freedom from suspended solids, the precipitation being very good throughout. The strongest sample, No. 3088A, represented the sewage arriving at the works between 10.30 a.m. and 2.30 p.m. in dry weather in January, 1903, and—so far as the comparative figures go—was fully twice as strong as the sets of hourly samples. The weakest sample, No. 3331, was taken in wet weather, with the storm overflow at work, on December 7th, 1903, at 5 p.m.; as judged by the figures for total Nitrogen and for "Oxygen absorbed" in 4 hours, this was only about one-seventh or one-eighth as strong as No. 3088A. The filters at Chorley have therefore to treat at different times liquids of very varying strengths.

Although not of much value, because of the great variations in these chance samples of precipitation liquor, the following reduction figures as compared with the hourly samples of sewage may be given :—

Calculated on :—	Reduction.
"Oxygen Absorbed" *at once* - - - - - - -	62 per cent.
" " *in 4 hours* - - - - - - -	55 "
Solids in Suspension - - - - - - - -	93 "

Bacteriological Notes.—Twelve samples of precipitation liquor were examined. The results are shewn in the accompanying table. In view of the remarkably good settlement effected by the Chorley precipitation process, it is disappointing to find that the bacteriological results were not uniformly satisfactory. A few of the samples (3202B, 3331, 3407) showed, for a first process, a remarkable degree of purification, bacteriologically; but the majority yielded positive results with from 1/10,000 to 1/100,000 c.c. with the B. coli, neutral red broth, lactose peptone milk, and bile-salt glucose peptone tests. Most of the samples yielded positive results with the B. enteritidis sporogenes test with from 1/10 to 1/100 c.c.

Description of the Sample.	B. coli test.	In. = Indol test. N.R = Neutral red broth test. L.P.M. = Lactose peptone milk test. B.S. = Bile-salt glucose peptone test.	B. Enteritidis sporogenes test.	Remarks.
3204. Chorley crude sewage, 28/7/03	—	100,000 N.R.	100 not 1,000	
3045. Chorley precipitation liquor, 5/11/02	100,000 (– indol) (– clot)	10,000 not 100,000 In. 100,000 B.S.	100 not 1,000	
3088A. Chorley precipitation liquor, 12/1/03	10,000 not 100,000 (+indol) (+clot)	10,000 not 100,000 In. 1,000 not 10,000 N.R. 10,000 not 100,000 L.P.M.	10 not 100	160,000 and 54,000 (gelatine at 20°C. and agar at 37°C. respectively) microbes per c.c. 'Gas" test –·1 c.c. (24 hours at 20°C.).
487. Chorley precipitation liquor, 4/3/03	—	10,000 not 100,000 N.R. 10,000 not 100,000 B.S.	10 not 100	
3192. Chorley precipitation liquor, 16/7/03	—	100,000 N.R.	10 not 100	
3202B. Chorley precipitation liquor, 28/7/03	—	1,000 not 10,000 N.R.	10 not 100	
3212B. Chorley precipitation liquor, 11/8/03	100,000 (+indol) (+clot)	100,000 N.R.	10 not 100	
3215B. Chorley precipitation liquor, 12/8/03	100,000 (– indol) (– clot)	100,000 N.R.	100 not 1,000	
3218B. Chorley precipitation liquor, 13/8/03	100,000 (+indol) (+clot)	100,000 N.R.	10 not 100	
3331. Chorley precipitation liquor, 7/12/03	—	Negative 1/100 c.c. N.R.	10 not 100	
3407. Chorley precipitation liquor, 29/2/04	1,000 not 10,000 (+indol) (+clot)	1,000 not 10,000 N.R.	1 not 10	
3474. Chorley precipitation liquor, 23/6/04	100,000 (+indol) (+clot)	10,000 not 100,000 In. 100,000 N.R. 100,000 L.P.M. 100,000 B.S.	10 not 100	
3522. Chorley precipitation liquor, 25/7/04	100,000 (+indol) (+clot)	100,000 N.R. 100,000 L.P.M. 100 000 B.S. 100,000 In.	10 not 100	

FILTERS.

Number - - - -	15, arranged in 5 sets of 3 each.
Size of each - - - -	9 filters, 57 feet by 16 feet; 6 filters, 114 feet by 16 feet.
Depth of material - - - - - - -	3 feet.
Area of each filter (approximately)	9 filters, 100 square yards; 6 filters, 200 square yards.
Total area - - - - - - -	2,127 square yards.
Cubic content of each (approximately)	9 filters, 100 cube yards; 6 filters, 200 cube yards.
Total cubic content - - - - -	2,127 cube yards.

Material.—Originally all the filters, excepting three which were used for experimental purposes, were constructed of sand, polarite and gravel, the grading from the top downwards being 9 inches sand, 9 inches polarite ($\frac{1}{4}$ in. diameter) and sand mixed, and 18 inches gravel and large stones, varying from 6 inches to $\frac{1}{4}$ inch diameter. Since then, but without altering the general construction of the filters or the grading of the materials, rather coarser sand has been put on the top of all the filters, and various other materials have been used in seven of them, in place of the polarite. The materials in the middle layer of the filters during our observations have been as follows:—

8 filters - - - - - - -	polarite and sand
3 filters - - - - - -	magnetite and gravel
3 filters - - - - - - -	polarite and gravel.
1 filter - - - - - - - -	coke breeze.

Construction.—The filters are constructed of brick walls with cement bottoms, and lie below the level of the ground. They are arranged in series of three each, the filters in each series being connected with one another by means of openings under the two dividing walls. The object of this is to allow of washing the beds, an operation which is described in a later paragraph. They are underdrained by means of six rows of 3-inch horse-shoe drains, laid the whole length of the bed, and these fall to a pipe constituting the outlet drain, which is laid laterally across the three beds of a series at the outlet ends.

Distribution.—At the end of each filter section there is a small tank or syphon chamber, holding for the small beds 2,300 gallons and for the large beds 2,700 gallons. By means of a hand valve, tank liquor is allowed to flow into these chambers at a rate sufficient to fill them for the small filters once in forty minutes, and for the large filters once in twenty minutes. When the tank liquor in the chamber rises to a certain height, a syphon placed in it comes into action and the contents of the whole chamber are rapidly discharged. The distribution of this discharge upon the filters is effected by means of a single deep wooden trough, laid down the centre of each filter upon the surface of the sand. The sides of this trough are perforated with a number of small holes, and when the syphon chamber delivering tank liquor to the section discharges its contents, the liquid quickly traverses the length of the trough, and then flows laterally through the perforations and across the sand to the side walls, which are rather less than 8 feet from the trough, the beds being on an average only 16 feet broad. As a general rule, the whole surface of a filter is covered with tank liquor in less than two minutes, and the syphon chambers also empty themselves in about the same time. The effectiveness of the distribution really lies in the rapidity with which the syphon chambers discharge, and the Chorley Authorities have therefore made special experiments upon this. Three kinds of syphon have been tried; the first was constructed by Messrs. Goddard, Massey and Warner, the second from a design by the Manager of the works, and the third by Messrs. Adams and Co., of York, and all three still continue in operation. We consider each kind to be effective.

Working.—The quiescent settlement of the precipitated sewage does away with all variations of the flow after the liquor has entered the tanks, and the rate at which the filters work is consequently under complete control. The method followed

during our observations has been to keep the rate at which the filters work quite constant, and to vary the number of filters in use, according to the amount of liquid to be dealt with. As a general rule, twelve filters are in use at one time; the others are either resting or being washed. When a bed is brought into use, it usually works for 12 hours a day for five days, receiving tank liquor during this time, if it is a small bed, in flushes of 2,300 gallons every 40 minutes, or if it is a large bed, in flushes of 2,700 gallons every 20 minutes. The length of time that it works, and the rests given to it, depend of course on the amount of tank liquor to be treated, and there are no fixed rules in vogue; in wet weather, or at those times when there is a large quantity of tank liquor to be filtered, the beds may be kept in use both night and day. There is no rule, either, for the number of days that a filter shall work before it is put out of action, but it usually works for five days at a time.

Washing.—Although the tank liquor contains very small quantities of suspended matter, this is sufficient to clog the surface of the sand after a few (usually five) days' working. When this happens, the outlet valves of all three sections of a series are closed and tank liquor is allowed to flow on to two of the sections, so as to obtain a slow upward flow through the third. By opening the small penstock situated rather above the surface of the bed at the outlet end, a continuous flow can be maintained through the third bed, and while this lasts, the top few inches of the sand are agitated and loosened under water. This used to be done by hand raking, but a patent travelling rake is now used for the purpose.

When the sand has been sufficiently raked, the surface while still under water is swept over with a soft brush, and in this way the sludge deposited by the tank liquor is made to rise up into the wash water and so to be carried off the bed to a settling tank. From this tank, after settling, the liquid is pumped back to the precipitation tanks, and the sludge at the bottom is lifted by means of a chain pump and put on the ground near by. In the process of sweeping and agitating, some fine sand naturally rises into the wash water, and to prevent this being lost, the wash water is made to flow through several small catch-pits before it finally enters the settling tank. When the other two sections of the bed have also undergone this process, they are drained, and after a rest of about 12 hours are again ready for use. The washing of 3 sections occupies the time of one man for 8 hours.

Amount of Tank Liquor treated upon the Filters. — The whole of the tank liquor is not at all times treated upon the filters; for a short time almost every day, whether in dry or wet weather, some tank liquor is allowed to flow unfiltered into the main effluent channel. Although the quantity thus turned away is not great, it is sufficiently large to make a difference in any calculation of the amount treated upon the filters, and daily measurements of its volume have therefore been made over a considerable period of time, by means of an automatic recorder.

From July 26th, 1903, to May 31st, 1905—a period of six hundred and seventy-four days, there were only forty-three days on which some tank liquor was not turned away unfiltered, and the gauging records during this period show that the average amount turned away per day was 13,600 gallons, the largest quantity being 40,000 gallons, in August, 1904, and the smallest 3,000 gallons, in July, 1904. The discharge occupied from one to three and a half hours and varied, as to time of discharge, from 8 a.m. to 5 p.m.

The average amount of liquor flowing to the tanks for treatment during 1903-4 was 1,131,000 gallons, and the average amount turned away unfiltered in 1904-5 was about 13,600 gallons. Taking these as representing the same period, for purposes of calculation, the average amount filtered per day would be about 1,117,400 gallons, and upon this basis the following amounts were treated upon the filters at Chorley:—

Per square yard per 24 hours - - -	525 gallons.
Per cube yard per 24 hours - - -	525 gallons.

We think, however, that this is rather too high an estimate.

Effluents.—Of the filter effluents, four sets of hourly samples and thirteen chance samples were examined chemically. The hourly samples, Nos. 3203c, 3213c, 3216c and 3219c, drawn in equal quantities every hour, from all the filters then in

use, and at the same times and under the same conditions as the hourly samples of sewage and of precipitation liquor, gave the following results on analysis :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(1·03 to 1·42)	1·16	(4)
Albuminoid Nitrogen	*(0·08 to 0.14)	0·11	(4)
Total Organic Nitrogen	(0·18 to 0·39)	0·27	(3)
Oxidized Nitrogen	(1·91 to 2·42)	2·24	(4)
Total Nitrogen	(3·58 to 3·88)	3·69	(3)
"Oxygen absorbed" at 27°C. (80°F.) *at once*	(0·14 to 0·38)	0·28	(4)
" " " " *in 4 hours*	(0·82 to 1·45)	1·14	(4)
Chlorine	(7·66 to 10·08)	8·89	(4)
Incubator Test (Scudder)	2 passed, 2 failed slightly	—	(4)
Incubator Test (by smell)	† 4 passed	—	(4)
Smell when drawn	‡ 4 fairly good	—	(4)
Smell when analysed	§ 4 good	—	(4)
Solids in Suspension	‖ (0·48 and 0·57)	0·55	(2)
Solids by Centrifuge (vols.)	(3·5 to 10·0)	6·9	(4)

Like the hourly samples of sewage and of precipitation liquor, these hourly samples of effluent were of even composition and they were all very free from suspended solids; in appearance they were very faintly opalescent (one of them slightly turbid). They contained two-thirds of their total nitrogen in the oxidized state, gave comparatively low figures for "oxygen absorbed," and all withstood incubation. If we compare the figures of analysis with those given by the hourly sets of sewage and of precipitation liquor, we get the following reductions :—

	Reduction on :—			
	Sewage.		Precipitation Liquor.	
Total Nitrogen	40 %	(3)	21 %	(3)
Ammoniacal Nitrogen	71 "	(4)	68 "	(4)
Albuminoid Nitrogen	89 "	(4)	81 "	(4)
Total Organic Nitrogen	86 "	(3)	53 "	(3)
"Oxygen absorbed" *at once*	91 "	(4)	71 "	(4)
" *in 4 hours*	91 ,	(4)	77 "	(4)
Solids in Suspension	98 "	(2)	79 "	(2)

It is evident that the very rapid treatment of precipitation liquor upon the filters results in the oxidation of about four-fifths of the organic matter of the liquor, as measured by the "oxygen absorbed" test, and of about half the nitrogenous matter. There is on the other hand only a comparatively small actual loss of nitrogen.

* The figures for albuminoid nitrogen are probably rather high in two of the samples,
† Three of the four had a rather unpleasant vegetable smell after incubation.
‡ One was noted as having an unpleasant sweet smell when drawn, and the three others as having a strong wormy and rather doubtful smell.
§ For the most part an earthy and soapy smell,
‖ Equal quantities of the three last samples were mixed together for this estimation.

Chance Samples.—Thirteen chance samples in all were examined chemically, viz., Nos. 3046, 3088B, 488, 3193, 3194, 3200, 3332, 3408, 707, 3475 3476, 3477 and 3520. These were taken pretty well at all times of the year, for the most part in dry weather, and at hours varying between 10.40 a.m. and 8.40 p.m. They gave the following results on analysis* :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(0·11 to 1·61)	0·56	(9)
Albuminoid Nitrogen †	(0·03 to 0·41)	0·11	(9)
Oxidized Nitrogen	(0·80 to 6·48)	3·00	(12)
"Oxygen absorbed" at 27° C. (80° F,) *at once*	(0·02 to 0·67)	0·23	(12)
" " " *in 4 hours*	(0·36 to 2·90)	0·98	(12)
Dissolved Oxygen taken up in 24 hours at about 18° C. (65° F.)	(0·11 to 0·31)	0·18	(7)
Chlorine	(3·46 to 7·46)	5·85	(4)
Incubator Test (Scudder)	8 passed 4 failed slightly	—	(12)
Incubator Test (by smell)	12 passed	—	(12)
Smell when drawn	8 good	—	(8)
Smell when analysed	11 good 1 doubtful	—	(12)
Solids by Centrifuge (volumes)	(0·0 to 26·0)	4·7	(12)
c. c. per litre.			
Oxygen in solution when analysed	(1·35 to 7·40)	4·0	(7)

The above effluents were almost all clear or very faintly opalescent, with but a trace of sediment on the average, and all, with possibly one exception, had a perfectly clean smell when they came to be analysed. Further, they were all well nitrated, and they withstood incubation in every case. The last seven samples were found to be, approximately, half saturated with oxygen on the morning of analysis, and they took up very little oxygen from solution when incubated for 24 hours at 18° C.—not much more than 1 c. c. per litre or 0·18 part by weight of oxygen per 100,000 (this estimation was made with less precision in the first five samples.) These chance samples of effluent may thus as a whole be classed as very satisfactory from a chemical point of view. Taking them all over, they were better than the hourly samples, no doubt from the fact of the latter having been drawn in summer when the sewage was necessarily more concentrated.‡

When the figures of analysis of these effluents are compared with those of the hourly sets of sewage and of precipitation liquor, they show the following reductions :—

	Reduction on :—	
	Sewage.	Precipitation Liquor.
Ammoniacal Nitrogen	86 %	85%
Albuminoid Nitrogen	89 „	81 „
"Oxygen absorbed" *at once*	93 „	77 „
" " *in 4 hours*	92 „	80 „
Solids by Centrifuge (vols.)	98 „	85 „

* The figures for 3193 and 3194 have been averaged together as one analysis; the samples were from one discharge of the same bed, but taken at different times.

† Probably rather high in the case of No 3205 (Albuminoid Nitrogen, 0·12).

‡ It may be added that three samples of Chorley effluent, which were examined so long ago as January and February, 1899, were well nitrated liquids of the same type as the above effluents generally.

The following notes of individual samples may be found to be of some interest :—

Samples No. 3193 and 3194 were from the same discharge of a bed which had been resting for 10 hours. No. 3193 was drawn shortly after the bed had received its flush of precipitation liquor, while No. 3194 constituted the last part of the discharge. The former contained more nitrate, but also more suspended solids than the latter, though both were well nitrated. At Chorley, therefore, as at places with other systems of sewage purification, the first flush from a bed, after the latter has been resting, brings out solids with it.

The actual figures referred to were :—

	No. 3293.	No. 3294.
Oxidized Nitrogen (approximately) - - - - -	4·2	2·8
Solids in Suspension - - - - - - - -	2·36	0·66

Again, effluents Nos. 3475, 3476 and 3477 each correspond separately to the precipitation liquor No. 3474. No. 3475 was drawn from a coke bed, No. 3476 from a polarite bed and No. 3477 from a magnetite bed. All three effluents were very good. The effect of the long rest which the two last beds had received is evident from the large quantities of nitrate which were present in these effluents.

The following comparative figures (parts per 100,000 by weight) for absorption of dissolved oxygen may also be cited here :—

Number of Sample.	Diluted with :—	Dissolved oxygen taken up at about 18°C in :—				
		24 Hours.	48 Hours.	72 Hours.	96 Hours.	144 Hours.
3408	2 vols. tap water -	0·12	0·47	0·56	—	—
3476	2 vols. tap water -	0·15	—	0·43	—	—
3477	(*a*) None - -	0·14	—	0·38	0·49	—
,,	(*b*) 2 vols. tap water	0·01	—	0·18	0·25	—
3521	(*a*) None - - -	0·14	—	—	—	—
—	(*b*) 2 vols. tap water	0·09	0·19	—	—	0·68
707		—	—	—	—	—
(*a*)* Original Sample	2 vols. tap water	0·27	—	—	—	—
(*b*) Filtered through paper.	2 vols. tap water	0·07	—	—	—	—

(*a*)* This gave 6·7 vols. of centrifuge solids per 100,000, i.e., only a very small quantity.

Number of Sample.	Diluted with :—	Dissolved Oxygen taken up in :—		
		24 Hours at 18° C.	6 Hours at 27° C.	4 Hours at 37° C.
3200	2 vols. tap water -	0 31	0·13	0·17

These figures show, among other things, (1) that the absorption of dissolved oxygen by the above effluents was very slow; (2) that the Chorley effluent takes up rather more dissolved oxygen when incubated alone, after being ærated by shaking, than when incubated after æration with two volumes of tap water; (3) that the suspended solids in the effluent are largely responsible for what oxygen is taken up.

Special Effluent Samples.—No. 3409 represents a washing water effluent from Filter No. 2, which had been flooded all day previous to the taking of the sample. Judged from an effluent standard it was of high quality, containing very little organic

impurity, nearly 3 parts of nitric nitrogen, and taking up only 0·06 part of dissolved oxygen in 24 hours. It would thus appear that the material of the filter was very clean. Had it contained much suspended organic matter, so good an effluent could not have been obtained.

Comparison of the Purification effected by Polarite and Coke Filters respectively.—Since the samples, of which particulars have already been given, did not deal specially with the question whether polarite or coke filters gave the better results, it was thought advisable to supplement them by a few other sets of chance samples drawn at different times. Each set consisted of a sample of precipitation liquor, a coke filter effluent and a polarite filter effluent, the filters from which the effluents were taken having been worked similarly for three or four days beforehand, so that the conditions might be as uniform as possible in both cases.

The first set, Nos. 3675, 3676 and 3677, was drawn on Thursday, March 15th, 1906, at 2.30 to 2.55 p.m., in very wet weather; the second set, Nos. 1, 2 and 3, on Wednesday, April 18th, 1906, at 1.45 to 2.15 p.m., in dry weather; and the third set, Nos. 3681, 3682 and 3683, on Tuesday, May 8th, 1906, at 1.45 to 2.0 p.m., after a wet morning following fairly dry weather. The figures of analysis of the three precipitation liquors are appended below and they show that No. 3675 was very weak, that No. 1 was strong, especially as regards nitrogenous matter, while No. 3681 was weak, though stronger than the first sample. A little nitrate was found in each sample on the day of analysis. Only the middle sample (No. 1) contained any suspended solids, to speak of. The three samples thus represent precipitation liquors of different organic strength.

Precipitation Liquor—Experimental Samples. Parts per 100,000.	No. 3675.	No. 1.	No. 3681.
Ammoniacal Nitrogen	0·97	8·36	3·32
Albuminoid Nitrogen	0·20	0·68	0·56
Total Organic Nitrogen	0·64	1·06	0·83
Oxidized Nitrogen	0·39	0·43	0·30
Total Nitrogen	2·00	9·85	4·40
"Oxygen absorbed" at 27° C. (80° F.) *at once*	0·53	1·84	0·40
,, ,, ,, *in 4 hours.*	2·58	6·95	3·92
Dissolved Oxygen taken up from water at 18° C. *in 24 hours.*	1·00	7·86	3·34
Chlorine	3·72	9·90	6·00
Solids in Suspension	1·90	4·95	
Solids by Centrifuge (vols.)	Trace	24·4	4·8

The figures of analysis of the three corresponding pairs of effluents are also given separately. The chlorine figures corroborate the point that the same precipitation liquor was being treated upon the two kinds of filters. In the first pair of effluents, the one from the polarite filter was distinctly the better, in that it took up only about half the quantity of dissolved oxygen from water as compared with that taken up by the coke filter effluent. In the second set the coke filter effluent was slightly the better, and it was also, if anything, the better in the third set. But, taking all the figures together, we think that the conclusion may be drawn that neither effluent shows any marked superiority over the other.

Comparative Samples of Effluent from Coke and Polarite Filters. Parts per 100,000.	Coke. No. 3676	Polarite. No. 3677	Coke No. 2	Polarite. No. 3	Coke. No. 3683	Polarite. No. 3682
Ammoniacal Nitrogen - - - - - -	0·59	0·86	3·80	3·48	1·01	1·15
Albuminoid Nitrogen - - - - - -	0·05	0·07	0·09	0·11	0·08	0·09
Total Organic Nitrogen - - - - - -	0·11	0·07	0·09	0·24	0·10	0·33
Nitric Nitrogen - - - - - - - -	1·27	1·08	1·01	0·94	1·74	1·74
Nitrous Nitrogen - - - - - - -	Trace	0·01	0·01	0·01	Trace	Trace
Total Nitrogen - - - - - - - -	1·97	2·00	4·88	4·67	2·81	3·22
"Oxygen absorbed" *at once* at 27° C. - -	0·16	0·19	0·26	0·24	0·33	0·36
"Oxygen absorbed" *in* 4 *hours* - - - - -	0·50	0·65	0·72	0·81	1·19	1·17
Dissolved Oxygen taken up from water at 18° C. *in* 24 *hours* - - - - - -	0·05	0·06	0·24	0·37	0·71	0·38
Dissolved Oxygen taken up from water at 18° C. *in* 5 *days* - - - - - - -	0·30	0·42	0·67	0·90	1·33	0·86
Incubator Test (Scudder) - - - - -	Passed	Passed	Passed	Passed	Passed	Passed
Incubator Test (by smell) - - - - -	Passed	Passed	Passed	Passed	Passed	Passed
Smell when drawn - - - - - -	Good	Good	Good	Good	Good	Good
Smell when analysed - - - - - -	Good	Good	Good	Good	Good	Good
Chlorine - - - - - - - - -	3·75	3·80	9·88	10·02	7·10	7·22
Solids by Centrifuge (vols) - - - -	1·4	1·1	2·4ap.	4·8	4·8	5·0

As already mentioned, a certain amount of precipitation liquor is sometimes mixed with the effluent before the latter is run into the stream. Two such mixed samples have been examined chemically, viz., No. 3205, drawn in August, 1903, this being an effluent from the sewage of 10 a.m. to 12 noon; the effluent, as discharged, contained about one-seventh of its volume of precipitation liquor. It gave an analysis almost the same as the hourly samples of effluent, excepting that it contained about four times as much suspended solids. The second admixed effluent examined, No. 3260, was drawn in October, 1903, and represented a storm water sewage of about 12 noon to 1 p.m. of the same day; the effluent, as discharged, contained about its own volume of the dilute precipitation liquor from this storm water sewage. This effluent, which was dilute, was of good quality, chemically speaking.

Bacteriological Notes.—The bacteriological results varied to a considerable extent, but some of the samples were certainly very good. Thus, five of the samples contained less than 10,000 (two of them less than 1,000) B. coli; and none of the samples contained 100,000 B. coli per c.c. The indol, neutral red broth, lactose peptone milk, and bile salt glucose peptone tests likewise yielded good results. Moreover, 7 out of 16 samples yielded negative results with the B. enteritidis sporogenes test with 1/10 c.c. Sample 3523 was taken when the flow from a filter was at its maximum. It contained a large amount of suspended matter, and it is of interest to note that the number of spores of B. enteritidis sporogenes was very large. The results are set forth in detail in the accompanying table, which includes also the results of the bacteriological examination of a few special samples. Sample 3260 was remarkably pure; it was a mixture of storm water precipitation liquor and filter effluent. Samples 3209 and 3210 were examples of sand washing liquor; they contained about the same number of bacteria of an intestinal type as an average sample of precipitation liquor. If B. coli were largely concerned in the process of sewage purification, it might perhaps have

been anticipated that the number of B. coli in the sand washing liquor would have been higher than was actually found to be the case. Sample **3409** was a filter effluent from a filter only just previously washed; the results were very good bacteriologically.

Description of Sample.	B. coli Test.	In = Indol test. N.R.=Neutral red broth test. L.P.M.=Lactose peptone milk test. B.S.=Bile-salt glucose peptone test.	B. Enteritidis Sporogenes test.	Remarks.
3046. Chorley filter effluent, 5/11/02.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 In. 10,000 not 100,000 B.S.	100 not 1,000	
3088B. Chorley filter effluent, 12/1/03.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 In. 1,000 not 10,000 N.R. 10,000 not 100,000 L.P.M.	10 not 100	32,000 and 19,000 (gelatine at 20° C. and agar at 37° C. respectively) microbes per c.c. "Gas" test – 1 c.c. (24 hours at 20° C.)
·488. Chorley filter effluent, 4/3/03.	—	1 000 not 10,000 N.R. 100 not 1,000 B.S.	1 not 10	
3193. Chorley filter effluent, 16/7/03.	—	100,000 N.R.	1 not 10	
3194. Chorley filter effluent, 16/7/03.	—	100,000 N.R.	10 not 100	
3200. Chorley filter effluent, 27/7/03.	—	10,000 not 100,000 N.R.	10 not 100	
3203C. Chorley filter effluent, 28/7/03.	—	10,000 not 100,000 N.R.	1 not 10	
2313C. Chorley filter effluent, 11/8/03.	100 not 1,000 (+ indol) (+ clot)	100 not 1,000 N.R.	10 not 100	
3216C. Chorley filter effluent, 12/8/03.	10,000 not 100,000 (– indol) (– clot)	10,000 not 100,000 N.R.	10 not 100	
3219C. Chorley filter effluent, 13/8/04.	1,000 not 10,000 (+ indol) (+ clot)	1,000 not 10 000 N.R.	1 not 10	
3332. Chorley filter effluent, 7/12/03.	—	Negative 1/100 c.c. N.R.	1 not 10	
3408. Chorley filter effluent 2/92/04.	100 not 1,000 (+ indol) (+ clot)	100 not 1,000 N.R.	1 not 10	
3475. (Chorley filter effluent, 23/6/04.)	10,000 not 100,000 (– indol) (+ clot)	10,000 not 100,000 In. 10,000 not 100,000 N.R. 10,000 not 100.000 L.P.M. 10,000 not 100,000 B.S.	1 not 10	
3476. Chorley filter effluent 23/6/04.	1,000 not 10,000 (– indol) (+ clot)	1,000 not 10,000 In. 100 not 1,000 L.P.M. 1,000 not 10,000 B.S.	10 not 100	
3521. Chorley filter effluent, 25/7/04.	1,000 not 10,000 (+ indol) (+ clot)	1,000 not 10,000 In. 100 not 1,000 N.R. 1,000 not 10,000 L.P.M. 1,000 not 10,000 B.S.	10 not 100	
3523. Chorley filter effluent, 25/7/04.	10,000 not 100,000 (– indol) (+ clot)	10,000 not 100,000 In. 1,000 not 10.000 N.R. 10,000 not 100,000 L.P.M. 10,000 not 100,000 B.S.	1,000 not 10,000	

Description of Sample.	B. coli test.	In=Indol test. N.R.=Neutral red broth test. L.P.M. = Lactose peptone milk test. B.S.=Bile-salt glucose peptone test.	B. Enteritidis Sporogenes test.	Remarks.
3209. Chorley sand washing liquor, 10/8/03.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 N-R.	100 not 1,000	
3210. Chorley sand washing liquor, 10/8/03.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R.	10 not 100	
3260. Chorley "works" effluent, 13/10/03.	—	Negative 1/100 c.c.	1 not 10	
3409. Chorley filter effluent from *washed* filter, 29/2/04.	100 not 1,000 (+ indol) (+ clot)	100 not 1,000 N.R.	Negative 1 c.c.	
3261. Chorley storm water overflow discharge sample, 13/10/03.	100,000 (+indol) (+ clot)	100,000 N.R.	100 not 1,000	

Effect of Temperature upon the Working of the Filters.—The process of sewage disposal carried out at Chorley renders a considerable exposure of the liquid necessary, and we have therefore made careful observations of the temperatures of the various liquids. Average temperatures taken every few hours over a period of three weeks, in July, 1903, showed that in warm weather there was a slight rise in the temperature of the liquid as it went through the process, and special temperature measurements made in the winter showed that the reverse took place during cold weather. On several occasions the temperature of the final effluent was found to be as low at 5° Centigrade; and on one occasion in January, 1903, during frost (atmosphere 0°C.), it went down to 4° Centigrade, the liquid having lost 3°C. in the process of filtration. The figures of analysis of the effluent sample, No. 3088B., which was drawn on that day, indicated that the efficiency of the filter had been impaired by the low temperature.

SUMMARY.

Chorley sewage is a domestic one of about average strength, with practically no trade refuse in it. It is liable to be greatly diluted in times of storm, owing to the admission of the water of the river Chor into the sewers, and also because the sewers receive, in the form of surface water, part of the rain which falls upon the drainage area, as well as some subsoil water.

The precipitation effected at Chorley is uniformly excellent. As compared with the hourly samples of sewage, the hourly samples of precipitation liquor showed a reduction in suspended solids of 91 per cent., and the chance samples a reduction of 93 per cent., the actual average figures for solids in suspension in the precipitation liquor being :—hourly samples, 2·9 parts per 100,000; chance samples, 2·1 parts. This result is to be ascribed to the good quality of the precipitant used and to the quiescent settlement, while it is also possible that the nature of the water entering the sewers may render some additional help. The fact of the precipitant being made with great care on the works tends to ensure uniformity in its composition. The precipitation at Chorley may be taken as an excellent illustration of the advantages of quiescent settlement.

No difficulty is found in pressing the precipitation sludge with lime or in disposing of it when pressed (at 1s. 6d. a load) to the neighbouring farmers. Neither the working of the tanks nor the sludging is attended with any nuisance, if one excepts the slight smell at the entrance screen and in the press house. The sewage works, in fact, are unusually free from smell.

The filters are composed of a surface layer of sand, a middle layer of either polarite, magnetite or coke, the pieces composing this middle layer being of equal size throughout, and a bottom layer of gravel, varying from a quarter of an inch to six inches in diameter. By an experiment extending over twelve months, the authorities satisfied themselves some time ago that there was very little difference in the quality of the effluents from two filters, one of which had a middle layer of polarite and the other a middle layer of coke. Our own observations upon this particular point confirm that conclusion.

The unusual method of filtration followed results in large flushes of liquid passing very rapidly through the filters, but on the other hand the whole of the filtering area comes into use. We have made no special study as to how nitrification is brought about in these filters, but the action must be a very rapid one; besides being well nitrated, the effluent issuing from the filters is well aerated also. The process is not one which leads to the loss of much nitrogen in the form of gas; hence it may, perhaps, be referred to as being mainly an oxidising and not a destructive process, as regards the nitrogenous matter in the liquid treated.

The effluent is of good quality chemically, though the hourly samples examined had a slightly suspicious smell when drawn, and were not quite up to the standard of the chance samples. The effluent takes up very little dissolved oxygen from solution, and every sample which we examined withstood the incubator test. Bacteriologically the results varied to a considerable extent, but some of the samples were certainly very good.

We are unable to give the exact figures for the rate of filtration, but the volume of precipitation liquor treated per cube yard is approximately 450 to 500 gallons, a very large quantity. As some precipitation liquor is discharged from the works unfiltered almost every day (not more than two or three times the dry weather flow being treated at any time), it would appear that the filters are now working up to their full capacity.

With regard to the procedure adopted, of mixing a certain amount of unfiltered precipitation liquor with purified effluent—although the two samples of such admixed liquor examined were found to be of good quality, it should be remembered that they were in both cases drawn during or after heavy rainfall. Although, therefore, these particular samples were satisfactory, the advisability of the procedure appears to us to be doubtful; the probability is that it can only be carried out at Chorley because the precipitation liquor there is not very strong and is usually free from suspended solids.

The filter beds have now (1904) been in operation since 1895, without having deteriorated in any way. It was however found advisable, at an early stage of the working, to replace some of the very fine sand of the surface layer by coarser sand, and to remove all admixed sand from the middle layer, as this tended to cause clogging.

Good results are obtained in every part of the process and little or no nuisance arises from it.

We may perhaps be allowed to add, in conclusion, that the good results are due to the long continued and careful experiments made in connection with its various details by Sir Henry Hibbert, Mr. Alderman Stone, Mr. Leigh, the Borough Surveyor, and Mr. T. Hurst, the manager. We are greatly indebted to these gentlemen for much assistance in connection with our work at Chorley.

CLIFTON SEWAGE WORKS.

(Barton-upon-Irwell Rural District Council.)

1 Situation of works - - - - - -	About ¼ mile from Clifton.
2. Method of treatment - - - - -	Continuous flow settlement followed by continuous flow filtration through very fine material.
3. Population draining to works during observations	2,000 (approximately).
4. Water supply in gallons per head and whence obtained - - - - - - -	17·7 approximately. From the Bolton water supply (soft moorland water).
5. Average dry weather flow of sewage in gallons per 24 hours - - - - - -	22,000.
6. Gallons of sewage per head per day - -	11.
7. Number of water closets - - - - -	50.
8. Character of the sewage - - - -	Strong slop-water domestic sewage.
9. Sewerage system - - - - - -	Partially separate.
10. Period of observations - - - - -	November, 1903 to July, 1905.
11. Age of filter beds - - - - - -	5½ and 12 years.
12. Amount of storm water dealt with - - -	About 5 times the dry weather flow.
13. Capacity of settling tank in gallons - -	4,875.
14. Total area of filter beds in yards super - -	1,054.
15. Total capacity of filter beds in yards cube -	1,405.
16. Nature of filtering medium - - -	Boiler clinker and cinder, clay, soil, gravel and sand.
17. Gallons of settled sewage treated per yard super per 24 hours. All filters included - -	20·8.
18. Gallons of settled sewage treated per yard cube per 24 hours. All filters included - -	15·6.
19. The final effluent is discharged into - -	A small beck which flows into the river Irwell.

FLOW OF SEWAGE.

Although the sewerage of the district is upon the partially separate system, the flow of sewage becomes much increased during rain, and as there is only one storm-overflow on the system, and this situated on the main sewer close to the works, the whole volume of storm-water and sewage is brought to this point. Here, however, any excess above six times the dry weather flow of sewage is diverted, this volume being the maximum which the tank and filters are called upon to treat.

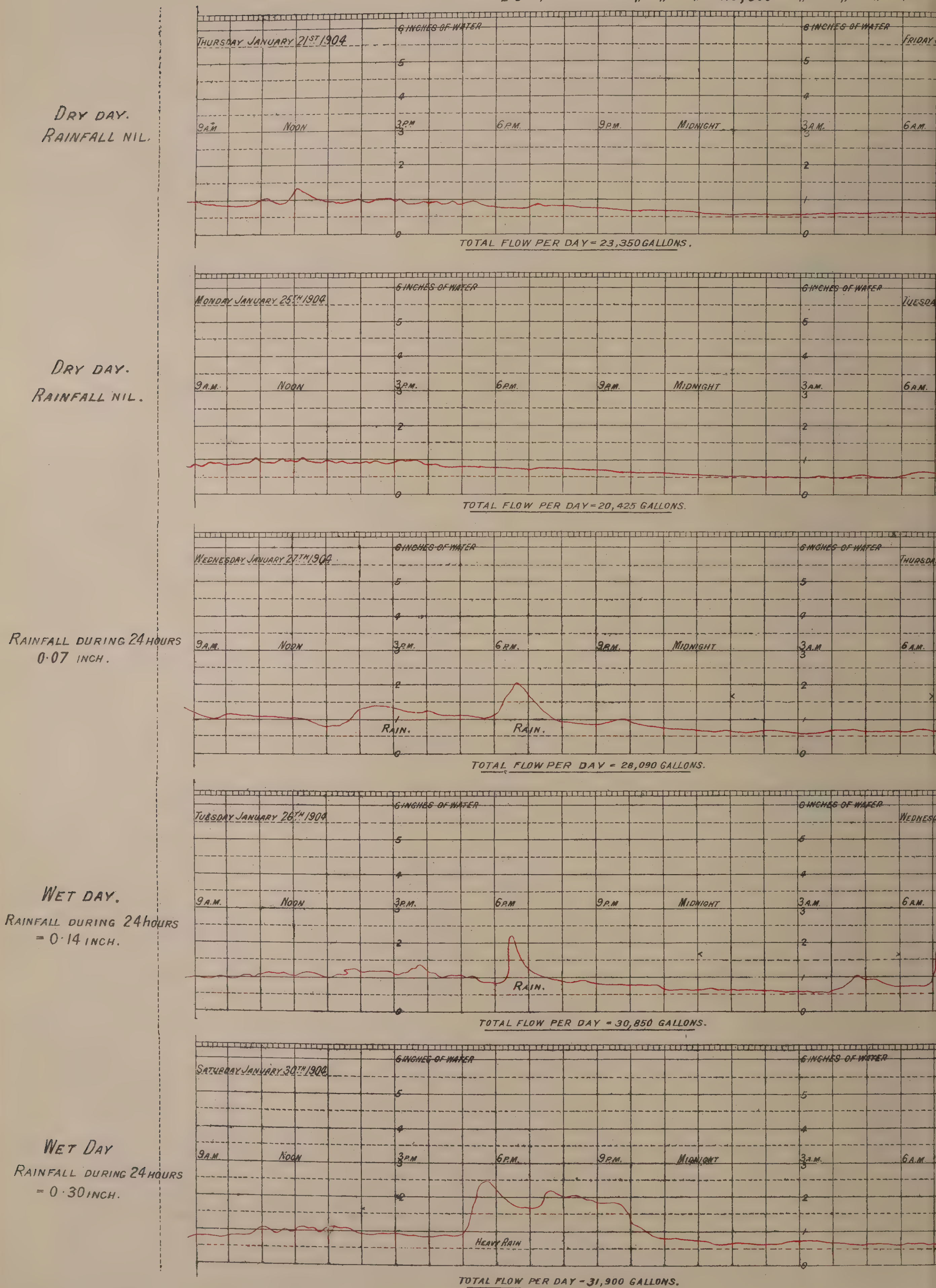
Diagram G.

DIAGRAMS SHOWING FLOW OF SEWAGE AT CLIFTON

AS FALLING OVER A WEIR 8" WIDE.

Note:- Over a Weir 8" wide

·5 of an inch	= a rate of	9,907 gallons	per 24 hours.
1·0 inch	= " " "	27,864 "	" " "
1·5 inches	= " " "	51,000 "	" " "
2·0 "	= " " "	78,480 "	" " "
2·5 "	= " " "	110,500 "	" " "



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The highest rate of flow measured during the gauging operations in January, 1904, was 103,000 gallons per 24 hours, this being the result of a fall of ·30 inch of rain within a period of five hours.

The flow of sewage was measured continuously for a period of 14 days in January and February, 1904. The first week of this period was a perfectly dry one, and as it followed upon dry weather, the flow recorded may be taken as the dry weather flow.

The average daily flow during this week was approximately 22,000 gallons.

The greatest flow (29,000 gallons per 24 hours) occurred on the Tuesday of the week, and the lowest (19,000 gallons per 24 hours) on the Sunday. Except on Tuesday mornings and afternoons, when a great deal of wash water reaches the works, the flow during dry weather is of a fairly even character, the general variation being a gradual fall from a slightly fluctuating rate of something like 29,000 gallons per 24 hours, which continues from 9 a.m. till 4 p.m., to a steady night flow at the rate of about 13,000 gallons per 24 hours. During wet weather the fluctuations are large and rapid, this being no doubt due, in some measure, to the fairly steep gradient of the main sewer.

Subsoil Water.—As the flow of night sewage is fairly high in ordinary dry weather, and the effect of rain upon the volume of sewage continues to be apparent for some days, it may be concluded that a considerable quantity of subsoil or ground water gains access to the sewers.

On diagram G. are given some typical illustrations of the sewage flow at Clifton.

Crude Sewage.—Five samples were examined chemically, viz.: three hourly sets of 24 hours each, drawn according to rate of flow, one of weakest night sewage, and one of storm sewage. During the three days on which the hourly samples, Nos. 3367, 3370 and 3378, were being taken, in January, 1904, the rainfall amounted to 0·0, 0·14 and 0·07 inch; these cannot, therefore, be called strictly dry weather samples, but the effect of the rainfall on the flow was apparently slight. The sample of weak night sewage, No. 3375, was drawn during the third day of the hourly sets. The very strong sample of storm sewage, No. 3126, was taken on March 17th, 1903, 11.10 a.m., at about two-thirds through the flow of storm sewage, there having been sharp rain between 10.15 and 10.45 a.m.

The following results were obtained:—

——— Parts per 100,000.	Hourly Samples, Average.	Number of Estimations.	Chance, No. 3375, Weak night Sewage.	Sample No. 3126, Storm Sewage.
Ammoniacal Nitrogen - - (3·47 to 3·98)	3·78	(3)	1·92	4·78
Albuminoid Nitrogen - - - (0·91 to 1·38)	1·11	(3)	0·19	2·42
Oxidized Nitrogen - - - - - -	0·0	(3)	0·23 ap.†	—
Total Organic Nitrogen - - (*1·22 to 3·25)	2·26	(3)	?	—
Total Nitrogen - - - - (*4·69 to 7·15)	6·05	(3)	2·24	—
"Oxygen absorbed" *at once* at 27° C. (4·40 to 7·20)	5·84	(3)	0·46	17·80
" " *in 4 hours* - (20·21 to 30·44)	26·07	(3)	1·62	45·40
Chlorine - - - - - - (8·22 to 10·78)	9·54	(3)	7·20	—
Solids in Suspension - - - (33·2 to 58·2)	49·1	(3)	3·2	198·0
Solids by Centrifuge (*vols.*) - (331 to 524 ap.)	460·0	(3)	34·0	—
Ratio of Solids in Suspension to Centrifuge Solids - - (1 : 9·4, 9·0 and 10·0)	1 : 9·5	(3)	1 : 10·6	—

* These two figures are almost certainly too low, owing to an accident. † "Ap." means "approximate."

It is seen from the foregoing figures that the crude sewage is of a very strong soapy character. The sets of hourly samples contained large quantities of black, flocculent and greasy suspended matter and had a soapy-sewage smell, the last two sets having also a strong scent of lemons. The sample of weakest night sewage, drawn in January, 1904, at 2 a.m., was very dilute, and contained a little oxidized nitrogen, no doubt from subsoil water. The sample of storm water sewage, No. 3126, is instructive as showing how very impure is the liquid first washed out of the sewers after a period of dry weather: it contained no less than 198 parts of suspended solids, of which 117 parts were volatile on heating.

Bacteriological Notes.—For results, *see* under Settled Sewage.

SETTLING TANK.

Number	1.
Size	39 feet by 5 feet.
Working depth	4 feet.
Capacity	4,875 gallons.

Construction.—The settling tank is constructed of brick and cement, with a concrete bottom. After having passed down a small cascade from the main sewer, the sewage enters the tank over a sill extending practically across the whole width of the inlet end, and issues again over a small sill or ledge at the outlet end. There are no sludge valves to the tank.

Working.—The settling tank receives the whole flow of sewage, day and night, except at those times when it is stopped for cleaning. During these stoppages the sewage is sent direct on to one of the filters.

Flow through.—With a dry weather flow of 22,000 gallons per 24 hours, the flow through the tank would be once in 5·3 hours, at the rate of 1·7 inches per minute.

Sludging.—The length of time for which the tank can be run without cleaning depends very largely upon the weather. In times of rain, and especially in showery weather, the tank may become half full of sludge in three or four weeks. Usually, however, in dry weather, it retains sufficient capacity to last for about five weeks; at the end of this time, owing to the sludge beginning to ferment, cleaning becomes necessary, whether the tank contains a large quantity of sludge or not. The cleaning is done as follows:—

Having siphoned off the supernatant liquid by means of a moveable siphon pipe, the sludge is lifted from the tank by a chain pump, worked by hand, and deposited in a cart drawn up at the side of the tank. The sewage in the meanwhile runs direct to the filters. The operation occupies the time of one man for about two days of eight hours each. Although some smell arises from the sludge, it does not entail any serious nuisance. The sludge is taken away by a farmer, under contract, the Council paying him £5 a year to take it. He uses it as a top dressing for grass land.

Settled Sewage.—Eight samples were examined chemically, viz., 3 sets of hourly and 5 chance samples. The hourly samples, Nos. 3368, 3371 and 3377, were drawn at the same time and under the same conditions as the hourly sets of crude sewage, the flow through the tank being about once in 5 hours. The two series of hourly sewage samples, crude and settled, are very comparable with one another. They yielded the following results:—

——	Parts per 100,000	Average.	Number of Estimations.
Ammoniacal Nitrogen	(3·07 to 4·51)	3·96	(3)
Albuminoid Nitrogen	(0·51 to 1·02)	0·76	(3)
Oxidized Nitrogen	-	0·0	(3)
Total Organic Nitrogen	(1·01 to 2·04)	1·51	(3)
Total Nitrogen	(4·07 to 6·34)	5·46	(3)
Oxygen absorbed "*at once*" at 27°C.	(3·04 to 4·51)	3·74	(3)
" " *in 4 hours*	(11·34 to 17·24)	15·13	(3)
Chlorine	(8·12 to 10·74)	9·56	(3)
Solids in Suspension	(21·4 to 26·9)	24·2	(3)
Solids by Centrifuge (Vols.)	(98·0 to 173·0)	148·0	(3)
Ratio of Solids in Suspension to Centrifuge Solids	(1:7·1, 6·4 and 4·6)	1:6·0	(3)

Like the hourly sets of crude sewage, the settled sewage of the third day was distinctly weaker than that of the first and second. When analysed, the samples were noted as having a soapy sewage smell, a strong sour tank smell, and a soapy and tank smell. The middle sample, No. 3371, contained some slaughter-house refuse.

Comparing these with the hourly samples of crude sewage, we find the following reduction in figures:—

Calculated on :—	Reduction.
Total Nitrogen	10 per cent.
Albuminoid Nitrogen	31 " " approx.
Total Organic Nitrogen	33 " " "
"Oxygen absorbed" *at once*	36 " "
" " *in 4 hours*	42 " "
Solids in Suspension	51 " "

The settlement in the tank thus reduces the solids in suspension of the crude sewage by about one-half, and the organic matter generally—as judged by the figures for organic nitrogen and permanganate absorption—by about one-third. The liquid left for the filters to treat is still strong and soapy and contains 24 parts per 100,000 of suspended solids—a high figure.

The five chance samples of settled sewage examined chemically, Nos. 3041, 3078, 3401A, 3554 and 3585, were drawn during the autumn and winter months of 1902 and 1904, between the hours of 12·55 noon and 5 p.m., all of them—practically speaking—in dry weather.

They yielded the following results, among others:—

——	Parts per 100,000	Average.	Number of Estimations.
Total Nitrogen	(4·75 to 6·63)	5·39	(4)
"Oxygen absorbed" *at once*	(3·26 to 10·40)	5·08	(5)
" " *in 4 hours*	(17·74 to 25·44)	20·64	(5)
Chlorine	(9·06 to 11·94)	10·74	(3)
Solids by Centrifuge (Vols.)	(126·0 to 328·0)	187.0	(5)

These samples, generally speaking, had a strong sewage or partly soapy smell on the day of analysis and they contained much suspended matter. Comparing the above figures with those given by the hourly samples of settled sewage, the chance ones are seen to be the stronger as regards oxidizable matter, as measured by the "oxygen absorbed" test, though the difference in strength would not have been very great if we had excluded the exceptionally strong sample, No. 3041, drawn at 2·40 p.m. on a washing day in dry weather.

Comparing them with the hourly samples of crude sewage, the following reduction in figures is arrived at:—

Calculated on :—	Reduction.
Total Nitrogen	11 per cent.
"Oxygen absorbed" *at once*	13 "
" " *in 4 hours*	21 "
Solids by Centrifuge (vols.)	59 "

Bacteriological Notes.—One sample of crude sewage and six samples of settled sewage were examined. The samples usually contained at least 100,000 B. coli and 100 spores of B. enteritidis sporogenes per c.c. The neutral red broth, lactose peptone milk, indol and bile-salt glucose peptone tests commonly gave a positive result with ·00001 c.c. (100,000 per c.c.). Sample 3368, however, yielded remarkable results for a settled

sewage. The B. coli and neutral red broth tests yielded negative results with ·0001 c.c. (1/10,000 c.c.) and there were no spores of B. enteritidis sporogenes in 1 c.c. But the chemical figures were normal and it is difficult to suggest any explanation of this apparently anomalous result.

Description of the Sample.	B. coli test.	N.R. = Neutral red broth test. In. = Indol test. L.P.M. = Lactose peptone milk test. B.S. = Bile-salt glucose peptone test.	B. enteritidis sporogenes test.	Remarks.
3126. Clifton Crude Sewage, 17/3/03.	–	N.R. = 100,000 B.S. = 100,000	100 not 1,000	
3041. Clifton Settled Sewage, 4/11/02.	100,000 (+ indol) (+ clot)	N.R. = 100,000 In. = 100,000	100 not 1,000	
3078. Clifton Settled Sewage. 17/12/02.	100,000 (+ indol) (+ clot)	N.R. = 100,000 In. = 100,000 L.P.M. = 100,000 B.S. = 100,000	100 not 1,000	Number of microbes (agar. at 37° C.) = 6 million per c.c. "Gas" test + .0001 c.c. (24 hours at 20°C.).
3368. Clifton Settled Sewage, 26/1/04.	1,000 not 10,000 (– indol) (+ clot)	N.R. = 1,000 not 10,000	Negative 1 c.c.	
3524. Clifton Settled Sewage, 26/7/04.	100,000 (+ indol) (– clot)	N.R. = 100,000 L.P.M. = 100,000 B.S. = 100,000	100 not 1,100	
3554. Clifton Settled Sewage, 13/10/04.	100,000 (– indol) (+ clot)	N.R. = 100,000 B.S. = 100,000	100 not 1,000	
3585. Clifton Settled Sewage, 20/12/04.	10,000 not 100,000 (+ indol) (+ clot)	N.R. = 100,000 B.S. = 10,000 not 100,000	100 not 1,000	

FILTERS.

Number - - - - -	4.
Size of each - - - - -	No. 1—237·2 square yards. No. 2—113·3 " " No. 3—336·1 " " No. 4—367·3 " "
Total area - - - - -	1,054 square yards.
Depth of material - - - -	4 feet.
Total cubic content - - -	1,405 cube yards.
Material - - - - - -	No. 1 filter :— (Top) 6 inches of fine cinders ; 2 feet 6 inches of rough cinders. (Bottom) 1 foot of gravel. No. 2 filter :— 4 feet of Cinders of all sizes. Nos. 3 and 4 filters :— (Top) 1 foot of coarse sand ; 3 feet of cinders.

Construction.—All the filters are constructed by simple excavation in the bottom of the clough. The underdraining varies according to the size of the filter. No. 4, which is the largest, has two cross drains, consisting of six-inch agricultural pipes unjointed, on each side of the main invert in the bottom of the clough; Nos. 2 and 3 have one cross drain on each side of the invert, and No. 1 is drained only by the invert itself.

Distribution. — The fine material placed on the surface of the filters renders it unnecessary to have any mechanical distributor. The settled sewage is therefore delivered from one or more points straight on to the surface of the filter in use. At one time the crude sewage (and, later, the settled sewage) was first allowed to trickle through the grass down the side of the clough and so to find its way on to the filter; but except upon one side of a single filter, this method of feeding has now been abandoned, as it made the banks very wet and sodden.

When a filter is brought into use after having been rested, and especially if it has been scraped during the rest, the settled sewage sinks rapidly into the material near the delivery pipe, and this, as will be seen later, sometimes results in bad effluents. In course of time, however, owing to the clogging of the material where the settled sewage is finding its way downwards, the liquid gradually spreads until the greater part of the filter surface becomes ponded.

Working.—The usual plan of working is to feed two filters for about six hours each during the day, and then to turn the settled sewage on to No. 2 filter for the whole of the night. There are no fixed rules, however, and the number of times that a bed is brought into use, and the length of the period during which it is worked, vary very much according to the state of the surface material and the volume of sewage arriving at the works. The two main principles upon which the filters are worked by the man in charge are:—

(1) That the settled sewage shall not find its way into the material too rapidly; and

(2) That the filter shall not be continued in use after it has become ponded.

Sometimes in wet weather it has been found necessary, in order to deal with the sewage reaching the works, to run the filters in a completely ponded condition; but this does not happen often, and, as a rule, a bed is cut off when it is four-fifths covered.

The surfaces of the filters are scraped on the average once in three months. The scrapings are heaped on the works.

Age of Filters.—Nos. 2 and 3 were brought into use in the spring of 1898; Nos. 3 and 4 have been in constant operation since 1891.

Amount of settled sewage treated upon the filters.—On the basis of the dry weather flow, which is estimated at approximately 22,000 gallons per 24 hours, the filters treat the following quantities of settled sewage:—

Per square yard per 24 hours - - - -	20·8 gallons.
Per cube yard per 24 hours - - - -	15·6 gallons.

These figures are obtained by dividing the total area or the total cubic content into the dry weather flow. Since, however, the filters are generally worked singly, the actual rate of flow through the particular filter in use is much greater.

Effluents.—Hourly Samples.—Three sets of hourly samples and seven chance samples were examined chemically. The hourly samples, Nos. 3369, 3372 and 3376, drawn according to the rate of flow of the settled sewage, at the same time as the

hourly samples of crude and of settled sewage, were remarkably uniform in composition throughout. They gave the following figures :—

	Parts per 100,000	Average.	Number of Estimations.
Ammoniacal Nitrogen	(0·75 to 0·86)	0·80	(3)
* Albuminoid Nitrogen	(0·09 to 0·11)	0·10	(3)
Total Organic Nitrogen	(0·22 to 0·32)	0·26	(3)
Oxidized Nitrogen	(0·71 to 0·94)	0·82	(3)
Total Nitrogen	(1·72 to 2·01)	1·88	(3)
"Oxygen absorbed" *at once* at 27° C. or 80° F.	(0·29 to 0·36)	0·32	(3)
" " *in 4 hours*	(1·00 to 1·19)	1·10	(3)
Chlorine	(6·30 to 7·12)	6·83	(3)
Incubator test (Scudder)		3 passed	(3)
" " (by smell)		3 passed	(3)
Smell when drawn		1 Earthy. 2 Slight sewage	(3)
Smell when analysed		2 Earthy. 1 Slight sewage	(3)
Solids in Suspension	(2·8 to 3·5)	3·3	(3)
Solids by Centrifuge (vols.)	(40·0 to 67·0)	52·0	(3)
Ratio of solids in Suspension to Centrifuge solids	1 : 19·1, 14·3 and 14·3	1 : 15·9	(3)

In appearance these effluents were brownish and rather turbid, from the presence of apparently a considerable quantity of very flocculent buff-coloured suspended matter. The two first had an earthy smell and the third a slight sewage smell—it must, however, have been very slight—when they came to be analysed. It will be seen, by comparing the chlorine figures of these effluents with those of the hourly samples of crude and settled sewage, that they were respectively :—

	Chlorine.
Effluent	6·83
Settled Sewage	9·56
Crude Sewage	9·54

It would appear, therefore, that the effluent was diluted with ground water, probably in the proportion of about two parts of effluent proper to one part of water. We were aware of the existence of this water before the samples were taken, and endeavoured to intercept it, but—as the result shows—with only partial success. With this proviso, it will be seen that the effluents were of very fair, though not of the highest, quality (see chance samples). They all withstood incubation, without using up much of their nitrate. The buff-coloured solids present, which were extremely flocculent, consisted of organic and inorganic matter in about equal proportions.

As compared with the hourly samples of crude and of settled sewage, these hourly samples of effluent show the following percentage reduction in figures :—

Calculated on :—	Crude Sewage.	Settled Sewage.
Total Nitrogen	69 per cent. reduction.	66 per cent. reduction.
Ammoniacal Nitrogen	79 "	80 "
Albuminoid Nitrogen	91 "	87 "
Total Organic Nitrogen	88 "	83 "
"Oxygen absorbed" *at once*	95 "	93 "
" " *in 4 hours*	96 "	93 "
Solids in Suspension	89 "	65 "
Solids by Centrifuge (Vols.)	91 "	87 "

* The figures given for albuminoid nitrogen in the effluents, both hourly and chance, are probably a little too high.

As already mentioned, when referring to the figures for chlorine, these reduction figures require to be lowered by about one-third, to get at the true values.

Chance Samples.—In addition to the hourly samples, seven chance samples of effluent were examined chemically, viz., Nos. 3042, 3079, 3403c, 708, 3525, 3555 and 3586. These were drawn at various seasons of the year, between the hours of 10.30 a.m. and 5.45 p.m.—nearly all of them in dry weather.

They gave the following results :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(0·63 to 1·32)	0·95	(3)
Albuminoid Nitrogen	(0·10 to 0·37)	0·20	(3)
Oxidized Nitrogen	(0·78 to 2·02 approx.)	1·16	(7)
"Oxygen absorbed" *at once* at 27°C.	(0·14 to 0·83)	0·42	(7)
,, ,, *in 4 hours*	(0·91 to 5·70)	2·06	(7)
Dissolved Oxygen taken up in 24 hours at about 18° C.	(0·23* to 2·34)	0·93	(7)
Chlorine	(6·96 to 8·86)	7·86	(4)
Incubator Test (Scudder)		5 passed 1 failed	(6)
,, ,, (by smell)		5 passed 2 failed	(7)
Smell when drawn		3 good ; 3 soapy or sewage ; 1 doubtful	(6)
Smell when analysed		4 good ; 2 earthy and soapy ; 1 rather sour	(7)
Solids in Suspension	(2·90 to 7·40)	5·60	(5)
Solids by Centrifuge (Vols.)	(13.0 to 65·0)	37·6	(5)
Ratio of Solids in Suspension to Centrifuge Solids	(1 : 5·5 to 1 : 10·8)	1 : 7·1	(4)

Four of the above chance samples were noted, when drawn, as probably containing some admixed water, and no doubt this held good for the other three also. In general appearance they were more or less like the hourly samples of effluent, and they filtered through paper to a bright and clear liquid. A glance at the above figures is sufficient to show that these effluents were far from even in composition, and a word or two may be said about them individually.

No. 3042, drawn when the bed had received its full complement of settled sewage, and was completely ponded, and which probably contained drainings from other beds, was a sample of high quality (*e.g.*, it took up very little dissolved oxygen from water in 48 hours, and the other figures of analysis were also good).

No. 3079, drawn one hour after the effluent had begun to flow from the bed, *i.e.*, shortly after the bed been brought into use after a rest, was a poor sample, and failed to withstand incubation.

No. 3403c, drawn when the bed was completely ponded after having been fed with settled sewage for six hours, was of fair quality, apart from the 7·4 parts of suspended solids that it contained. Even with these, it withstood incubation, though it took up 0·63 part of dissolved oxygen in 24 hours.

No. 708, drawn probably after the two beds had been in use for about 3½ hours, the sewage being very dilute, was good, apart from its 6 parts of suspended solids—very good indeed after filtration through paper (*e.g.* Dissolved oxygen absorption in 24 hours :—Original effluent 0·62 ; paper-filtered effluent 0·10).

No. 3525, drawn after the bed had been in use for 4 hours, and when it was one-third ponded, the surface material being rather looser than usual, was also good, and very good after paper filtration (*e.g.* Dissolved oxygen absorption in 24 hours :—Original effluent 0·38 ; paper-filtered effluent 0·07).

* In 48 hours at laboratory temperature.

No. **3555**, drawn after the bed had been in use for **7** hours, and was one-third ponded, also good, excepting for its **5** parts of suspended solids.

No. **3586**, drawn from three beds, all of which were completely ponded, and which had been in use for periods varying from $3\frac{1}{2}$ to about **20** hours, was a poor sample, which failed to withstand incubation.

It has been already seen that, taking the effluents generally, as exemplified in the hourly samples, they are of good quality. On the other hand, the chance samples show that their quality varies greatly, according to the length of time which elapses between the starting of a bed and the drawing of the sample. Broadly speaking, the liquid which passes through first, does so rapidly and results in a poor effluent. As the distribution improves, the effluent also improves up to a certain period, which is reached soon after the bed has become completely ponded; after this, again, the effluent falls off in quality.

The chance samples of effluent from Clifton varied so much in composition that any comparative "reduction" figures are of small value, but one or two may be given here, to be contrasted with those from the hourly samples of effluent.

Calculated on :—	Crude Sewage.	Settled Sewage.
"Oxygen absorbed" *at once* - . - - - -	**93** per cent. reduction.	**89** per cent. reduction,
,, ,, *in* **4** *hours* - - - - - - -	**92** ,, ,,	**86** ,, ,,
Solids in Suspension - - - - - - - -	**89** ,, ,,	**77** ,, ,,
Solids by Centrifuge (vols.) - - - - - -	**92** ,, ,,	**74** ,, ,,

The following figures are of interest, as showing to what extent the flocculent solids in the better effluents affect their purity:—

Number of Sample	**708.**		**3525.**		**3555.**		
	Original.	Filtered thro' paper.	Original.	Filtered thro' paper.	Original.	Filtered thro' paper.	Settled for **2** Days.
Solids in suspension - - - - -	**6·00**	—	**2·90**	—	**5·10**	—	—
"Oxygen absorbed" *at once* at 27° C.	**0·38**	**0·38**	**0·28**	**0·29**	**0·66**	**0·23**	**0·26**
,, ,, *in* **4** *hours* - -	**0·99**	**0·58**	**1·18**	**0·84**	**1·70**	**0·93**	**1·04**
Incubator Tests - - - - - -	Passed	Passed	Passed	Passed	Passed	Passed, practically.	Passed
Dissolved Oxygen taken up at about **18°** C. in **24** hours - - - - -	**0·62**	**0·10**	**0·38**	**0·07**	**0·42**	**0·20**	**0·32**
Ditto. ditto in **48** hours - -	—	—	**0·53**	**0·14**	—	—	—

These figures, more especially those for dissolved oxygen absorption, show that any impurity in the better effluents is largely due to the flocculent suspended solids which they contain; but even those solids do not take up oxygen at a rapid rate, as is seen by the figures for "oxygen absorbed from permanganate" *at once*, given by Nos. **708** and **3525**, and by the comparative figures for dissolved oxygen absorption in **24** and in **48** hours, given by No. **3525**. Apart from the suspended solids, the three effluents in question were of excellent quality, chemically.

Bacteriological Notes.—The results of the bacteriological examination of the Clifton effluents are shewn in the accompanying table. The effluents usually contained **10** to **100** (but more often **10** than **100**) spores of B. enteritidis sporogenes per c.c. As judged by B. coli, neutral red broth, indol, lactose peptone milk and bile salt glucose

peptone tests, the worst effluents yielded positive results with from ·0001 c.c. (10,000 per c.c.) to ·00001 c.c. (100,000 per c.c.), but the best effluents yielded negative results with from ·0001 c.c. (1/10,000 c.c.) to ·001 c.c. (1/1000 c.c.) Only two out of nine samples contained 100,000 B. coli per c.c. Many of the coli-like microbes isolated from the effluents failed to produce indol in broth culture and clot in milk culture. A virulent strain of a microbe, indistinguishable from B. pyocyaneus, was isolated from 1/100 c.c. of effluent No. 3042.

For an artificial process of sewage purification the bacteriological results have been usually good, but, in this connexion, the mechanical composition of the beds, the comparatively small volume treated per cubic yard, and the nature of the sewage must be taken into consideration.

Description of Sample.	B. Coli Test.	N.R.=Neutral Red Broth Test. In.=Indol Test. L.P.M.=Lactose Peptone Milk Test. B.S.=Bile Salt Glucose Peptone Test.	B. Enteritidis Sporogenes Test.	Remarks.
3042. Clifton Effluent, 4/11/02.	100,000 (— indol) (+ clot)	N.R.=100,000 In.=100,000	10 not 100	Virulent B. Pyocyaneus isolated from 1/100 c.c.
3079. Clifton Effluent, 17/12/02.	100,000 (— indol) (— clot)	N.R.=100,000 In.=100,000 L.P.M.=10,000 not 100,000 B.S.=100,000	10 not 100	Number of microbes (agar at 37° C.) 322,000 per c.c. "Gas" test + ·001 c.c. (24 hrs. at 20°C.)
3369. Clifton Effluent, 26/1/04.	100 not 1,000 (— indol) (— clot)	N.R.=100,000	10 not 100	
3372. Clifton Effluent, 27/1/04.	10,000 not 100,000 (— indol) (— clot)	N.R.=10,000 not 100,000	100 not 1,000	
3376. Clifton Effluent, 28/1/04.	100 not 1,000 (— indol) (+ clot)	N.R. 100 not 1,000	10 not 100	
3402B. Clifton Effluent, 24/2/04.	1,000 not 10,000 (+ indol) (+ clot)	N.R.=1,000 not 10,000	10 not 100	
708. Clifton Effluent, 15/6/04.	—	N.R.=10,000 not 100,000 In.=1,000 not 10,000 B.S.=10,000 not 100,000	10 not 100	
3525. Clifton Effluent, 26/7/04.	1,000 not 10,000 (+ indol) (— clot)	N.R.=10,000 not 100,000 L.P.M.=10,000 not 100,000 B.S.=1,000 not 10,000	1 not 10	
3555. Clifton Effluent, 13/10/04.	100 not 1,000 (— indol) (— clot)	N.R.=1,000 not 10,000 B.S.=100 not 1,000	100 not 1,000	
3586. Clifton Effluent, 20/12/04.	10,000 not 100,000 (+ indol) (+ clot)	N.R.=10,000 not 100,000 B.S.=10,000 not 100,000	100 not 1,000	

Effect of Temperature upon the working of the Filters.—The method of treatment at Clifton involves considerable exposure of the liquid on the surface of the filters. The temperature observations made are therefore interesting.* They show that instead

* The observations included isolated measurements made on the occasion of each visit to the works, several of these visits being made specially in cold weather, and also a set of temperatures taken every few hours for a period of four days, in January, 1904.

of taking its temperature from that of the sewage, as is usually the case, the effluent has a tendency to follow the atmosphere in temperature. Records of the working of the filters in prolonged severe weather would therefore be of great interest: but no such weather was experienced during our observations. The lowest effluent temperature measured was 4·8°C. (40·6°F.) On this occasion the temperature of the atmosphere was 2·2°C. (36°F.), that of the sewage 8·9°C. (48°F.), and that of the settled sewage about 7·2°C. (45°F.).

SUMMARY.

The crude sewage is of a very strong, soapy character, and the settled sewage which the filter beds treat is still strong and contains about 24 parts per 100,000 of suspended solids, or half the quantity present in the crude sewage. The settlement, while it does not compare with one in which precipitants are used, is effected at small cost of time and money. The emptying of the sewage sludge from the tank gives rise to a slight smell while it is being carried out, but there are no houses near the works, although a public footpath runs by them.

The filter beds are inexpensive, both as regards their construction and their working,—points of great moment for a small community.

The filters have been in operation for periods varying from six to fourteen years, and, referring more especially to those which are covered with sand, they seem to be in no danger of becoming permanently clogged. This may at first sight appear curious, seeing that they are treating a sewage containing so much suspended matter; but, these suspended solids are retained by the fine material on the surface of the bed, which is periodically scraped, and, further, the actual volume of settled sewage treated per cube yard of filter is only 15·6 gallons per 24 hours.

Excepting during the cleaning of the tank, and occasionally also at the sewage outfall, we have not observed any serious nuisance from smell at Clifton.

The system of sewage purification may be looked upon as being in a sense intermediate between land filtration proper and what is usually understood as artificial filtration. It has therefore a peculiar interest of its own, both chemically and bacteriologically.

The effluent, taken as a whole, is satisfactory, but the earlier portions of the liquid flowing from a bed which has just come into use after being rested are not sufficiently purified, owing to the imperfect distribution. This constitutes the weakest point of the system, and it might in some cases render the process inapplicable, without the addition of a separate form of distribution. Another danger which has to be guarded against is ponding of the beds for too long periods at a time, with resulting deterioration of the effluent. Lastly, it is necessary to point out that this method of sewage purification requires skilful management; should that be lacking, the results would certainly be unsatisfactory.

The effluent from the sewage works mixes, under the filter beds, with something like its own volume of surface water, the mixture then flowing rapidly in a succession of small waterfalls down the bed of the ravine, till it disappears in a pipe which carries it under a railway and a canal. The bed of the rivulet for this distance (about 100 yards) has always appeared clean during our observations, and there have been no signs of fungus.

We are indebted to Mr. C. C. Hooley, Surveyor to the Barton-upon-Irwell Rural District Council, and also to Mr. Patrick Curran, Manager of the works, for assistance during the observations.

EXETER SEWAGE WORKS (MAIN WORKS).

(CORPORATION OF EXETER).

1.	Situation of works	Belle Isle, close to the City of Exeter.
2.	Method of treatment	Closed septic tanks and single contact filtration, followed by land treatment. (Exeter Septic Tank Syndicate.)
3.	Population draining to works during observations	38,000 (estimated average.)
4.	Water supply in gallons per head, and whence obtained	25 gallons : the river Exe—a soft water.
5.	Number of W.C's	12,300
6.	Sewerage system	Combined.
7.	Average dry weather flow of sewage in gallons per 24 hours	1,300,000
8.	Gallons of sewage per head per day	34·2
9.	Character of the sewage	A strong domestic sewage.*
10.	Period of observations	November, 1902 to September, 1905.
11.	Age of contact beds	3 months.
12.	Amount of storm water treated on filters during observations	Not much more than 2,500,000 gallons (of sewage and storm water together) is treated by the filters in 24 hours.
13.	Total capacity of tanks in gallons	1,440,000
14.	Total area of filters in yards super	12,000
15.	Cubic content of filters in yards cube	18,000
16.	Nature of filtering material	Furnace clinkers.
17.	Gallons of septic tank liquor treated per yard super per 24 hours, all filters included	83·3
18.	Gallons of septic tank liquor treated per yard cube per 24 hours, all filters included	55·5
19.	The final effluent is discharged into	The river Exe.

* The sewage consists of the discharge of about 12,300 water closets, mixed with waste liquors from two large and one or two small Breweries, one large Tannery, and two Paper Mills.

FLOW OF SEWAGE.

The City is drained upon the combined system, and a large proportion of the rain finds its way into the sewers. Owing, however, to the storm-overflows on the branch intercepting sewers, and to a large storm-overflow on the main sewer close to the works, not more than six* times the dry weather flow ever passes to the tanks.

As at present arranged, the automatic gear actuating the filters does not allow of the filling of more than about 25 beds per day, the contact being for a set period; in order to fill more beds than this, the syphons which regulate the contact would require to be re-set. At an estimated capacity of 35 per cent. of the original empty tank capacity, 25 fillings per day are equivalent to $2\frac{1}{2}$ million gallons; this is, therefore, the maximum quantity treated, and also the maximum which the filters are designed to treat. Any excess above this flows over a second overflow, situated between the tanks and the filters, on to a small plot of land (5 acres), close by. The soil of this plot is marl overlying water-logged gravel. When a small quantity of tank liquor is put upon it, the liquid sinks slowly into the subsoil water; but in times of heavy storm it ponds up on the surface of the land, and is eventually sent into the river by opening a plug in the bank.

The flow of sewage was gauged throughout a period of fourteen days, in June, 1903. The first half of this fortnight was wet, and gave facilities for wet weather gaugings only, but for the remainder of the time the gaugings continued in perfectly dry weather. It is more than probable, however, that the preceding wet weather affected to some extent the flow during the second week of the gauging, and that the estimates of the dry weather flow thus obtained are higher than they should be, although possibly not too high for the year in question, which was an abnormally wet one.

The average flow during the last seven days of the period mentioned above was 1,300,000 gallons per 24 hours, the highest flow being 1,435,000 gallons on the Tuesday, and the lowest 1,172,000 gallons on the Saturday.

As the figure obtained for dry weather flow by the above gaugings was known to be high, the estimate made by the authorities of a dry weather flow of 1,000,000 gallons has been taken for the calculations relating to the quantity of sewage treated.

The flow in dry weather is of a rather undulating character, the general daily variation being in the proportion of about four volumes in the daytime to one at night. In wet weather, unless heavy showers happen to be falling upon dry ground, the general variations of the sewage flow are not so marked, owing to the working of the storm overflows and also to the night flow becoming much swollen with ground water.

On diagram H are given some illustrations of the sewage flow at Exeter.

Crude Sewage.—In addition to four chance samples, the usual three sets of hourly samples extending over three days—Nos. 561, 564 and 567—were examined chemically. These were drawn in the latter part of June, 1903, the weather being dry on the first and third days of sampling, while 0·12 inch of rain fell on the second day. The following results were obtained:—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(4·34 to 5·02)	4·66	(3)
Albuminoid Nitrogen	(1·13 to 1·70)	1·37	(3)
Total Organic Nitrogen	(2·98 to 3·97)	3·23	(3)
Total Nitrogen	(7·62 to 8·31)	7·89	(3)
"Oxygen absorbed" at 27° C (80° F.) *at once*	(4·59 to 5·92)	5·44	(3)
" " " *in 4 hours*	(16·90 to 22·86)	19·86	(3)
Chlorine	(10·92 to 11·48)	11·20	(3)
Solids in suspension	(34·6 to 39·2)	37·2	(3)
Solids by centrifuge (vols.)	(195·0 to 342·0)	246·0	(3)
Ratio of solids in suspension to centrifuge solids	(1 : 5·1 to 1 : 8·7)	1 : 6·5	(3)

The above samples were pretty uniform in composition, though the rain of the second day diluted No. 564 to a certain extent. The samples all contained tan refuse and

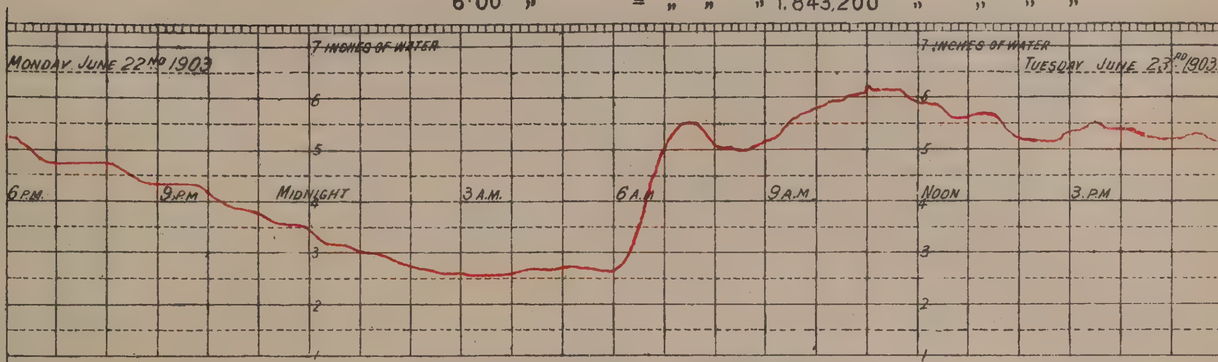
* This figure is, we understand, an estimate, and appears to us to be too high, but we have no actual gaugings.

Diagram H.

Diagrams showing flow of Sewage at Exeter (Main Works) as falling over a Weir 36" wide.

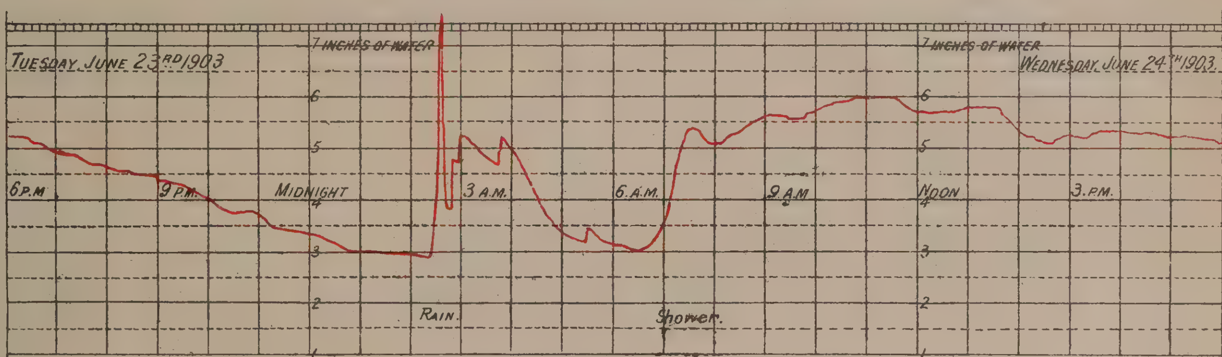
Note:- Over a Weir 36" wide, 2·50 inches = a rate of 495,360 gallons per 24 hours.
3·00 " = " " " 650,880 " " " "
4·00 " = " " " 1,000,800 " " " "
5·00 " = " " " 1,396,800 " " " "
6·00 " = " " " 1,843,200 " " " "

Y DAY.
FALL NIL.



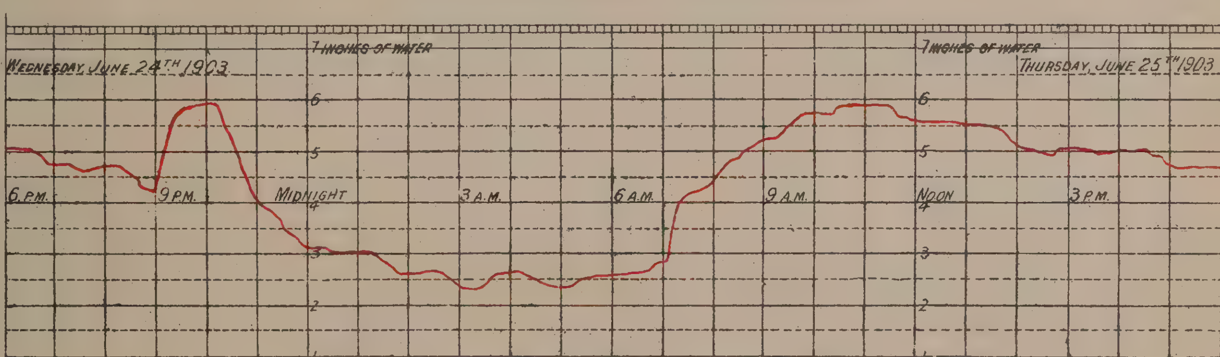
TOTAL FLOW FOR THE DAY = 1,338,300 GALLONS

ERY DAY.
LL 0.12 INCH.



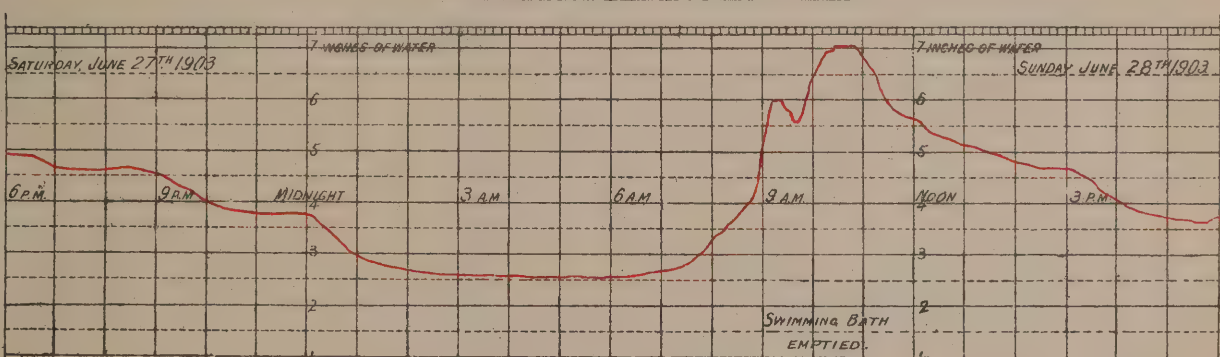
TOTAL FLOW FOR THE DAY = 1,435,000 GALLONS

DAY.
NIL.



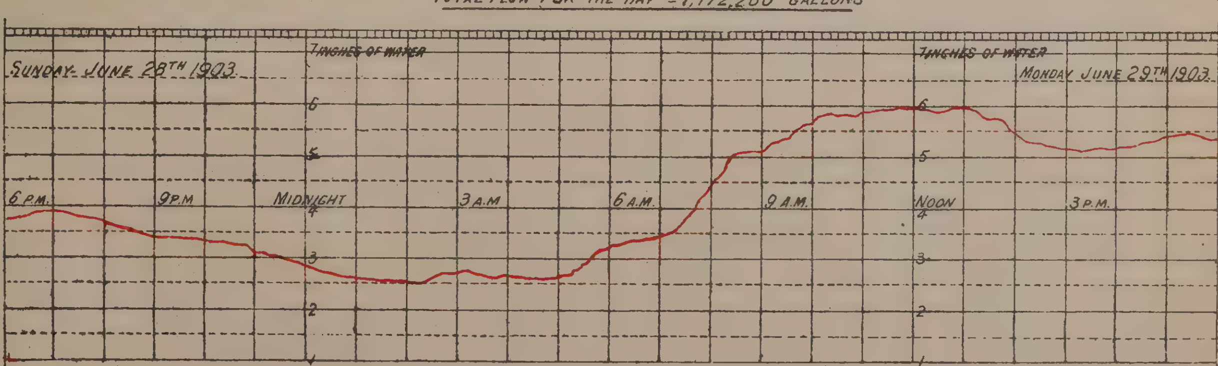
TOTAL FLOW FOR THE DAY = 1,302,000 GALLONS.

Y DAY.
LL NIL.



TOTAL FLOW FOR THE DAY = 1,172,200 GALLONS

DAY.
ALL NIL.



TOTAL FLOW FOR THE DAY = 1,200,600 GALLONS

Weller & Graham Ltd Litho London.

they all had a dark brown colour and more or less of a tan, as well as a sewage, smell; the presence of tan refuse no doubt accounts, in part, for the high figure for "oxygen absorbed" from permanganate (19·9). The nitrogen figure (7·9) is also fairly high, but the suspended solids (about 37 parts) are not excessive. The Works have thus to deal with a strong sewage.

Only two chance samples of sewage and two of storm water sewage were examined. The first chance sample of sewage, No. 3066, was drawn on November 26th, 1902, at 3.50 p.m., in wet weather, the storm overflow being then in operation; it had almost the same strength as the hourly samples (total nitrogen, 6·87; "oxygen absorbed" in 4 hours, 18·26; solids by centrifuge, 188). The second sample, No. 3108, drawn on February 26th, 1903, at 9 a.m., in dry weather following heavy rain, gave the figures:—total nitrogen, 7·93; "oxygen absorbed" in 4 hours, 12·91; solids by centrifuge, 119.

The figures for the two storm-water samples, Nos. 3144 and 616, are instructive (with regard to the question of settlement of storm waters):—

Parts per 100,000.	No. 3144.	No. 616.
Total Nitrogen	2·36	–
"Oxygen absorbed" at 27° C. (80° F.) *at once*	4·06	1·32
" " " " *in 4 hours*	20·10	6·58
Solids in suspension	408·1 < 47·4 Volatile, 360·7 Non-volatile	25·6 < 15·5 Volatile, 10·1 Non-volatile.

No. 3144 was drawn on May 5th, 1903, about 15 minutes after a heavy shower had set the storm overflow at work, while No. 616 was drawn in October of the same year, again fifteen minutes after the overflow had been started, but there having been heavy rain on the preceding night.

Bacteriological Notes: Crude Sewage.—The B. coli and presumptive tests for B. coli yielded in all cases positive results with $\frac{1}{100,000}$ c.c. (100,000 per c.c.). The B. enteritidis sporogenes test yielded positive results with from $\frac{1}{10}$ c.c. to $\frac{1}{10,000}$ c.c. (10 to 10,000 per c.c.).

Storm Overflow Discharge.—Four samples were examined. The B. coli and presumptive tests for B. coli yielded positive results with from $\frac{1}{10,000}$ to $\frac{1}{100,000}$ c.c. (10,000 to 100,000 per c.c.)

The B. enteritidis sporogenes test yielded the following results:—One sample contained 10, another sample contained 100, and the remaining two samples 1,000 spores of this anaerobe per c.c.

Crude Sewage.

Description of the Sample.	Number of B. coli (or gas-forming coli-like microbes).	B.S.=Bile-salt glucose peptone test. N.R.=Neutral red broth test. In=Indol test. L.P.M.=Lactose peptone milk test.	B. enteritidis sporogenes test.	Remarks.
MAIN WORKS.				
3066. Exeter crude sewage, 26/11/02.	100,000 (+indol) (+clot)	100,000 B.S. 100,000 N.R. 100,000 In. 100,000 L.P.M.	100 not 1,000	"Gas" test +·001 c.c. (24 hours at 20°C).
3108. Exeter crude sewage, 26/2/03.	100,000 (+indol) (+clot)	100,000 B.S. 100,000 N.R. 100,000 In.	10,000	
561. Exeter crude sewage, 23/6/03.	—	100,000 N.R.	10 not 100	
564. Exeter crude sewage, 24/6/03.	—	100,000 N.R.	1,000 not 10,000	
567. Exeter crude sewage, 25/6/03.	—	100,000 N.R.	1,000 not 10,000	

Storm overflow discharge.

Description of the Sample.	Number of B. coli (or gas-forming coli-like microbes).	B.S.=Bile-salt glucose peptone test. N.R.=Neutral red broth test. In.=Indol test. L.P.M.=Lactose peptone milk test.	B. enteritidis sporogenes test.	Remarks.
MAIN WORKS.				
3144. Exeter storm overflow liquid, 5/5/03.	—	10,000 not 100,000 N.R.	100 not 1,000	
3198. Exeter storm overflow liquid, 22/7/03.	—	100,000 N.R.	10 not 100	
614. Exeter storm overflow liquid, 6/10/03.	10,000 not 100,000 (+indol) (+clot)	10,000 not 100,000 N.R.	1,000 not 10,000	
616. Exeter storm overflow liquid, 6/10/03.	100,000 (—indol) (—clot)	100,000 N.R.	1,000 not 10,000	

GRIT CHAMBERS.

Before passing into the septic tanks, the sewage flows through 3 grit chambers, each about 20 feet long by 6 feet wide by 4 feet deep, and having each a capacity of about 3,000 gallons.

At the beginning of the observations the suspended matter which settled in these chambers was stirred up every morning and allowed to go forward into the septic tanks; but, as it was found to consist chiefly of gritty matter, it was afterwards removed from the chambers once a week, by ladling into barrows. It is used on the works for flower beds.

SEPTIC TANKS.

Number - - - -	6.
Size of each - - - -	177 feet by 36 feet.
Depth of water - - -	6 feet.
Capacity of each tank - -	240,000 gallons.
Total capacity - - -	1,440,000 gallons.

Construction.—The tanks are constructed of cement concrete throughout, each being covered in by triplicate arches, carried on 47 brick piers, and the whole roof having a layer of soil spread over it. There are no submerged walls in the tanks, but the brick piers no doubt have the effect, to some extent, of distributing the flow.

From the grit chambers the sewage passes to a channel carried along the end of the tanks. From there it falls into a second parallel channel, the entrance to the tanks being controlled by six valves, which open into the six tanks. The second channel is divided into six parts and valves are placed at the divisions, the arrangement being such that the sewage can be put through any desired number of tanks.

From the second channel four pipes lead off into each tank, delivering below the water level, and the tank liquor issues at the outlet end through a slotted pipe extending the whole width of each tank. This pipe is also placed below the water level.

Each tank is also fitted with six sludge valves, connected with slotted pipes, which are laid in grooves cut in the concrete bottom. These slotted pipes are about 9 feet apart and extend from the outlet end to about one-third of the way towards the inlet end of the tank.

Flow Through.—If all the tanks were in use at one time, the flow through, with a dry weather flow of one million gallons, would be once in 34·5 hours, at the rate of 1·03 inches per minute. As a rule, however, not more than two tanks are in use, and on this basis the flows through would be, in dry weather, once in 11·5 hours, at the rate of 3·09 inches per minute.

Working.—The tanks are used in parallel. When first brought into use in 1902, all six tanks were kept continually at work; but in that year some nuisance arose from the tank liquor, and as it was thought that this was due to the sewage having too long a stay in the tank, the plan of using only two tanks at a time, and resting the other four, was adopted. As the working tanks are changed once a month, each tank receives sewage for one month, and then rests for two months.

Sludging.—During the first year of their working (1902—1903), no sludge was removed from any of the tanks. Towards the end of 1903, however, the upper portion of the material in the beds became very clogged and sodden-looking; this was partly due, we think, to the amount of suspended matter issuing in the tank liquor, partly to the beds being filled with liquor to a depth of about six inches above the surface of the filtering material, the level of which was lower than it should have been, and partly to the abnormal rainfall of the year. From this time the sludge valves, or, as they were called, the "cleansing pipes," of the tanks were opened once a month, and the sludge was allowed to gravitate to one of the two sludge wells at the side of the tanks and pumped from there on to the made ground, close by, ground which consists of a deep deposit of fine clinker screenings. The operation is not attended with any serious nuisance.

We have not been able to make any measurement of the amount of sludge which has accumulated in the tanks, but it is probably by this time (1905) considerable. From our experience at other places, and especially because the tanks at Exeter are large and contain a great number of piers, it is difficult to believe that the periodical removal, from the outlet ends of the tanks, of what must be regarded as a comparatively small quantity of sludge will entirely obviate the necessity of an occasional complete sludging of the tanks—an operation which it appears to us will at these works be attended with some difficulty.

Septic Tank Liquor.—In addition to six chance samples, three sets of hourly samples, Nos. 562, 565 and 568, were examined chemically. These were drawn in June, 1903, under the same conditions as the hourly sets of sewage samples, *i.e.*, the first and third days were dry, but 0·12 inch of rain fell on the second day. As has been already stated, at the time those samples were drawn, the tank had been in use for about eighteen months.

The following results were obtained:—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(5·29 to 5·47)	5·40	(3)
Albuminoid Nitrogen	(0·76 to 1·03)	0·91	(3)
Total Organic Nitrogen	(1·43 to 2·05)	1·79	(3)
Total Nitrogen	(6·97 to 7·37)	7·23	(3)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(2·67 to 3·38)	2·99	(3)
,, ,, ,, ,, *in 4 hours*	(9·87 to 10·52)	10·20	(3)
Chlorine	(10·48 to 13·44)	12·17	(3)
Solids in suspension	(11·10 to 14·90)	12·50	(3)
Solids by centrifuge (vols.)	(37·0 to 58·0)	48·0	(3)
Ratio of solids in suspension to centrifuge solids	1 : 3·3 to 1 : 4·2	1 : 3·8	(3)

These hourly samples of septic tank liquor were of very uniform composition, though the suspended solids were rather higher in the second day's set than in the other two, no doubt because of the rainfall on that day. A glance at the above figures shows that the liquor is a strong one, containing much suspended solids; these are nearly twice as dense as the solids of the sewage.

As compared with the hourly samples of sewage, these hourly samples of septic tank liquor show the following reduction in figures:—

Calculated on :—	Reduction.
Total Nitrogen	8 per cent.
Albuminoid Nitrogen	34 "
Total Organic Nitrogen	45 "
"Oxygen absorbed" *at once*	45 "
" " *in 4 hours*	49 "
Solids in suspension	66 "

The six chance samples of Exeter septic tank liquor examined chemically, Nos. **3065**, **3109A**, **507**, **3146**, **3471** and **3543**, were drawn at all different seasons of the year, from November, **1902**, to August, **1904**. Though the weather was usually dry on the days that these were actually taken, it had for the most part been wet almost immediately before. The samples consequently show very great differences in composition, as is apparent from the following figures:—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(1·34 to 6·59 ap.)*	3·96	(3)
Albuminoid Nitrogen	(0·78 and 0·35)	–	–
Total Organic Nitrogen	(1·55 and 0·83)	–	–
Total Nitrogen	(2·17 to 7·96)	5·98	(5)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(1·65 to 3·38)	2·47	(6)
" " " " *in 4 hours*	(4·41 to 12·42)	8·73	(6)
Chlorine	(4·34 to 9·46)	7·18	(3)
Solids in suspension	(12·4 to 24·0)	16·10	(6)
Solids by centrifuge (vols.)	33·0 to 113·0)	60·0	(6)
Ratio of solids in suspension to centrifuge solids	(1 : 2·1 to 1 : 4·7)	1 : 3·3	(6)

These chance samples of septic tank liquor were for the most part brown and very turbid, with a tank smell, which was more or less pronounced according to the dilution. Sample No. **3065**, drawn in very wet weather, contained an appreciable quantity of nitrate. Taking them all over, they were distinctly weaker than the hourly samples, but they contained more suspended solids, the mean figure for this (16·0) being a very high one. In the two years during which these samples were taken no sludge was removed from the tank until the beginning of **1904**, after which a little was taken out monthly.

* Ap. = Approximate.

As compared with the hourly samples of sewage, these chance samples of septic tank liquor show the following reductions in figures :—

Calculated on :—	Reduction.
Total Nitrogen	34 per cent.
"Oxygen absorbed" *at once*	55 "
" " *in 4 hours*	56 "
Solids in suspension	57 "

Two samples of storm overflow liquor from the septic tank were also examined partially. The first of these, No. 3198, drawn on July 22nd, 1903, at 11.20 a.m., was the result of a short sharp thunder-shower at 10.30 a.m., on ground already wet from previous storms. The second, No. 614, was taken on the morning of October 6th, 1903, at 9.30 a.m., in showery weather following heavy rain in the preceding night.

These gave the figures :—

	No. 3198.	No. 614.
"Oxygen absorbed" *at once*	—	0·89
" " *in 4 hours*	7·19	4·19
Solids in suspension	17·9 < 8·2 volatile, 9·7 non-vol.	5·1 < 2·9 volatile, 2·2 non-vol.
Solids by centrifuge (vols.)	77·0	32·0
Ratio of solids in suspension to centrifuge solids	1 : 4·3	1 : 6·3

Bacteriological Notes.—Seven samples were examined bacteriologically. Practically all the samples yielded positive results with the B. coli test and presumptive tests for B. coli with 1/100,000 c.c. (100,000 per c.c.). Six out of the seven samples gave positive results with the B. enteritidis sporogenes test with 1/1,000 c.c. (1,000 per c.c.)

Description of the Sample.	Number of B. Coli (or Gas-forming Coli-like Microbes).	B.S.=Bile Salt Glucose Peptone Test. N.R.=Neutral Red Broth Test. In.=Indol Test. L.P.M.=Lactose Peptone Milk Test.	B. Enteritidis Sporogenes Test.	Remarks.
MAIN WORKS.				
3065. Exeter septic tank liquor. 26/11/02.	100,000 (+ indol) (+ clot)	100,000 B.S. 100,000 N.R. 100,000 In. 100,000 L.P.M.	1,000 not 10,000	"Gas" Test, + ·001 c.c. (24 hours at 20°C.)
3146. Exeter septic tank liquor. 5/5/03.	—	100,000 N.R.	100 not 1,000	
562. Exeter septic tank liquor. 23/6/03.	—	100,000 N.R.	1,000 not 10,000	
565. Exeter septic tank liquor. 24/6/03.	—	100,000 N.R.	1,000 not 10,000	
568. Exeter septic tank liquor. 25/6/03.	—	100,000 N.R.	1,000 not 10,000	
3471. Exeter septic tank liquor. 7/6/04.	10,000 not 100,000 (+ indol) (+ clot)	100,000 B.S. 100,000 N.R.	1,000 not 10,000	
3543. Exeter septic tank liquor. 18/8/04.	100,000 (+ indol) (+ clot)	100,000 B.S. 100,000 N.R.	1,000 not 10,000	

FILTERS.

Number - - - - -	12
Size of each - - - - -	About 1,000 square yards.
Total area - - - - -	12,000 square yards.
Depth of material - - - -	Originally 4 feet, but raised to 4 feet 6 inches in the spring of 1903.
Cubic content of each - - -	1,500 cube yards.
Total cubic content - - -	18,000 cube yards.

Material.—Furnace clinker which has passed a 1 inch mesh but has been rejected by a ½ inch mesh, with a bottom layer of coarser material, 6 inches thick, laid over the drains. Beds Nos. 1, 2, 3, 4, 5 and 8 have a bottom layer of coarse gravel 6 inches deep.

Construction.—Cement concrete throughout.

Distribution.—10 lines of 9-inch half pipes, laid on the surface of the material and fed through openings in the retaining walls from a main delivery channel.

Underdraining.—The underdraining is effected by means of about 37 lines of 4-inch agricultural pipes, 3 feet apart, laid on the concrete bottom. These are connected with a main outlet carrier (constructed underneath the main distributing channel), which discharges into the outlet chamber containing the discharge valve.

Working.—The filters are filled and empted automatically, by means of the siphonic gear designed by the Septic Tank Company.

There are three sets of gear for the twelve beds, and the beds are therefore worked in groups of four. Three filters in each of these groups constitute the working set, while the fourth filter is resting. The plan of working is to give the filters in each set a complete rest of two days in rotation.

Without working by hand, therefore, it is possible to fill three filters at any one time; but, as it has been considered advisable that the filters should fill as quickly as possible, the usual method of working during the observations has been to connect the three gears together and to fill only one filter at a time. The general state of working, therefore, is one filter filling, one filter full, and one filter discharging.

As soon as one of the filters is filled, a small quantity of filtered effluent flows from the discharge valve into its actuating bucket. The fall of this bucket closes the admission valve to the filter, but, on rising again after a proper interval has elapsed, owing to the siphoning out of its contents as the result of the discharge of the previous filter, it opens the discharge valve and releases the contents of the filter. The discharge of one full filter brings about the emptying of the actuating bucket in the next, and the counterweight of this then comes into play, closing its discharge valve and opening its admission valve. The overflow pipes from all the filters in a set are connected into a continuous ring, by means of a four-way cock placed at every junction. In this way a filter may be cut out of, or brought into, the working set.

During the observations, the time taken to fill a bed has been practically constant at three quarters to one hour, and the period of contact has been a fixed one of approximately an hour and a quarter. When the observations commenced, in November, 1902, upon beds which had been in use for less than a year, each bed was receiving on the average about 2 fillings per day, and at the end of the observations, in September, 1905, the average rate of working was approximately the same.

In the spring of 1903 the material on the surface of the beds became clogged and sodden looking, for the following reasons :—(1) the large amount of suspended matter in the tank liquor; (2) because the beds up to that time had been regularly overfilled to a depth of 6 inches; and (3) because of the wet weather prevailing for some time previously. The result of this was that the beds filled very slowly and, as only one could be filled at a time, the flow of tank liquor usually much exceeded the rate at which any one bed could receive it. At this time, therefore, the overflow situated between the tanks and the filters was very frequently in use, and on the occasion of one visit it was in use notwithstanding the fact that three beds were being filled at the time.

The addition of 6 inches of new material, in September, 1903, put a stop to this difficulty of working, by giving the bed surfaces a better chance to dry, and since that time the gear has worked satisfactorily again. But this inability of an automatic gear to adapt itself to the special circumstances which often arise at a sewage works constitutes its weak point, and the above experience is therefore instructive.

Age of Beds.—Some of the filters were first used at the end of 1901, and the others were brought into use as completed; they were all in operation in the summer of 1902.

Capacity.—The original total empty tank capacity of the 12 beds, when filled to a depth of 4 feet 6 inches, was 3,037,500 gallons, and on the assumption that the material, when first placed in position, occupied half the space of the tank, the total original water capacity was 1,518,750 gallons.

Owing to the large size of the beds and the narrowness of the delivery channels, it appeared for some time to be almost impossible to arrive at the capacity of the filters with any degree of accuracy, and, for this reason, the first part of the observations did not include any such measurements. Eventually, however, the necessity of forming some approximate estimate of the capacity of the beds was so evident that special steps had to be taken, and an approximate measurement was made in September, 1905, by filling one of the beds over an 18-inch weir, placed in a 2-foot channel. Taking the condition of this bed as typical of the whole filtering area,* the measurement gave a water capacity for the twelve beds of 828,000 gallons, *i.e.*, a capacity equal to 54·5 per cent. of the original water capacity, or 27·2 per cent. of the original empty tank capacity.

This estimate is only approximate; but it is thought to be sufficiently accurate to show that about 50 per cent. of the water capacity of the beds had been lost during the three years' working.

Amount of tank liquor treated upon the filters.—On the basis of a dry-weather flow of one million gallons per 24 hours, the following amounts are treated on the beds :—

Per square yard per day - - - - -	83·3 gallons.
Per cube yard per day - - - - - -	55·5 gallons.

Effluents, hourly samples.—Three sets of hourly samples of effluent and sixteen chance samples were examined chemically. The hourly samples, No. 563, 566 and 569, were drawn in June, 1903, a period of the year when sewage is naturally strong, at the same time and under the same conditions of weather as the hourly samples of sewage and of septic tank liquor. At the time they were drawn, the filters had been in use for 12 to 18 months. Each hourly sample of effluent was made up of equal quantities of all the contact bed discharges for the 24 hours, drawn at mid-flow.

* In order to verify the above, another measurement was made on October 9th, 1905, this time on bed No. 12. The result showed an approximate capacity of 64,000 gallons, which, if this bed is taken as typical, gives a total water capacity of 768,000 gallons. Based on this measurement, the water capacity of the whole twelve filters in October, 1905, was 50·5 per cent. of the original water capacity, or 25·2 per cent. of the original empty tank capacity.

They gave the following results :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(2·73 to 3·54)	3·12	(3)
Albuminoid Nitrogen *	(0·45 and 0·50)		(2)
Total Organic Nitrogen	(0·90)		(1)
Oxidized Nitrogen	(Trace to 0·61)	0·28 ap.	(3)
Total Nitrogen	(3·73 to 4·44)	4·00	(3)
"Oxygen absorbed" at 27°C. (80°F.) *at once*	(0·95 to 1·38)	1·12	(3)
" " " " *in 4 hours*	(3·25 to 4·35)	3·67	(3)
Incubator test (Scudder)			
Incubator test (by smell)		3 failed.	(3)
Smell when drawn		3 Sewage smell.	(3)
Smell when analysed		3 Ditto.	(3)
Chlorine	(9·34 to 13·00)	10·87	(3)
Solids in suspension	(3·76 to 5·84)	4·63	(3)
Solids by centrifuge (vols.)	(23·0 to 60·0)	42·0	(3)
Ratio of solids in suspension to centrifuge solids	(1 : 6·1 to 1 : 10·3)	1: 8·8	(3)

These three sets of hourly samples of effluent were of fairly uniform composition, though they increased in strength as the sampling went on. In appearance they were pale yellow in colour, and turbid from the presence of finely divided suspended matter. As will be seen from the figures of analysis, they were unsatisfactory in character if judged from the standpoint of a final effluent, *per se*, but, on the other hand, they showed a high percentage degree of purification by single contact, if contrasted with the hourly samples of sewage and of tank liquor. All of them had a distinct sewage smell, both when drawn and when analysed, and they all failed to withstand incubation; excepting in the first sample, there was practically no nitrate present in them on the day of analysis. The suspended solids, which were flocculent in character, averaged 4·6 parts per 100,000. It must, however, be borne in mind that this effluent was not a final one, but had still to be passed over land. (cf. notes on the chance samples of effluent).

As compared with the hourly samples of sewage and of tank liquor, the above hourly samples of effluent show the following reduction in figures :—

Calculated on :--	Sewage.	Septic Tank Liquor.
Total Nitrogen	49 per cent. reduction.	45 per cent. reduction.
"Oxygen absorbed" *at once*	79 " "	63 " "
" " *in 4 hours*	82 " "	64 " "
Solids in suspension	88 " "	63 " "

* Possibly slightly too high.

The sixteen chance samples of effluent examined were Nos. **3064**, **3109B**, **508**, **3146A**, **3199**, **3275**, **3337**, **3338**, **666**, **3470**, **3528**, **3544**, **3551**, **758**, **3621** and **3469**. The last was a "first flush," and contained much more matter in suspension and less nitrate than No. **3470**, which was drawn from the same emptying, but at mid-flow. Strictly speaking, No. **3469** ought not to be averaged with the other samples, but excepting that it raises the average figure for suspended solids in the effluents by about **0·5** part per **100,000**, its inclusion makes no material difference. The other fifteen were drawn at all seasons of the year, those in the cooler months predominating slightly, and two-thirds of them were taken either in wet weather or in dry weather immediately following wet. All of them were drawn at mid-flow, excepting No. **508**, which was at quarter-flow, and No. **3337**, at the end of the flow (this last sample consisted partly of drainings). The length of time of contact varied between three-quarters of an hour and three hours, but most of the samples received from one to one and a half hours' contact, reckoning from the time that the bed was completely full.

The following results were obtained :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(0·28 to 3·62 ap.)	1·61	(11)
Albuminoid Nitrogen *	(0·11 to 0·58)	0·31	(10)
Total Organic Nitrogen †	(0·43 to 1·44)	0·85	(5)
Oxidized Nitrogen	(0·10 ap. to 4·80 ap.)	1·58 ap.	(15)
Total Nitrogen	(2·38 to 6·26)	3·96	(6)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(0.24 to 2·61)	1·07	(15)
" " " " *in 4 hours*	(1·19 to 14·64 ‡)	4·35	(15)
Dissolved Oxygen taken up *in 24 hours* at about 18° C.	(0·0 ? to 4·76)	1·80 ap.	(9)
Incubator Test (Scudder)		7 passed 1 failed	(8)
" " (by smell)		7 passed 7 failed	(14)
Smell when drawn		10 good 4 bad or doubtful	(14)
Smell when analysed		13 good 2 doubtful	(15)
Chlorine	(5·18 to 11·24)	6·96	(6)
Solids in Suspension	(Trace to 11·40)	5·40	(11)
Solids by Centrifuge (vols.)	(Trace to 40·0)	23·0	(15)
Ratio of Solids in Suspension to Centrifuge Solids)	(1 : 1·8 to 1 : 7·7)	1 . 5·1	(10)

As will be seen from the foregoing figures of analysis, the chance samples of effluent varied greatly in composition, though, taking them all over, they were much better than the hourly samples. In appearance they were usually brownish and more or less turbid from suspended matter, but **10** out of **14** had a clean smell when they were drawn, and **13** out of **15** a clean smell on the day of analysis. All of them contained nitrate, mostly in considerable quantity, but **7** out of **14** failed to withstand incubation. The suspended solids averaged in eleven samples **5·4** parts, § and rose in one sample (the last examined) as high as **11·4** parts.

* Possibly rather high in No. **3109** B (Alb. N = **0·24**).

† Most of the estimations of organic nitrogen and of absorption of dissolved oxygen happened to be done on the poorer samples, and they do not therefore represent a true average.

‡ This figure was altogether abnormal, the next highest being **7·56**.

§ Excluding No. **3469** (suspended solids = **10·2**), the average figure was **5·0**.

It may be well at this point to refer shortly to some of the *average* figures of analysis of the last six samples, which were examined both before and after filtration through paper; at the same time it should be borne in mind that these six were below the average of the whole fifteen effluents in quality. They gave the comparative average figures :—

Parts per 100,000.	Original.	Filtered through paper.	Number of Estimations.
"Oxygen absorbed" at 27° C (80° F.) *at once* - - - -	1·47	1·03	(6)
" " " " " *in 4 hours* - - -	4·95	3·45	(6)
Dissolved oxygen taken up in 24 hours at about 18° C. - -	2·22 ap.	1·12	(6)
Incubator test (by smell) - - - - - - -	2 passed 4 failed	5 passed 1 failed	(6)

Taking all the results together, the chance samples of effluent were, as a rule, indifferent in quality, if regarded from the standpoint of a final effluent, *per se*, though better than the hourly samples. At the same time they would not have required very much further purification to allow of their reaching a reasonable standard of purity. The impurity was due to a considerable extent to the suspended solids which they contained. The effluents are rather better in reality than would at first sight appear from some of the figures of analysis, this being no doubt due to the fact of their coming from a strong tank liquor. Speaking generally, the best effluents examined were those which were dilute, *i.e.*, drawn in wet or showery weather. Towards the end of our observations some dry-weather samples were taken which were of very poor quality.

Compared with the hourly samples of sewage and of septic tank liquor, these chance samples of effluent show the following reduction in figures :—

Calculated on :—	Sewage.	Septic Tank Liquor.
Albuminoid Nitrogen - - - - - - - - -	77 % reduction	66 % reduction
"Oxygen absorbed" *at once* - - - - - - - -	80 " "	64 " "
" " *in 4 hours* - - - - - - -	78 " "	57 " "
Solids in suspension - - - - - - - - -	85 " "	67 " "

Bacteriological Notes.—Seventeen samples were examined. The great majority of the samples yielded positive results with the B. coli and presumptive tests for B. coli with 1/100,000 c.c. (100,000 per c.c.). As regards the B. enteritidis sporogenes test, the following results were obtained :—Eleven samples contained 100, 5 samples, 1,000, and 1 sample 10 spores of this anaerobe per c.c.

Description of the Sample.	Number of B. Coli (or gas-forming Coli-like microbes).	B.S. = Bile salt Glucose Peptone Test. N.R. = Neutral Red Broth Test. In. = Indol Test. L.P.M. = Lactose Peptone Milk Test.	B. Enteritidis Sporogenes Test.	Remarks.
MAIN WORKS.				
3064. Exeter final effluent. 26/11/02.	100,000 (+ indol) (+ clot)	100,000 B.S. 100,000 N.R. 100,000 In.	100 not 1,000	Gas Test + ·01 c.c. (24 hours at 20°C.)
3109B. Exeter final effluent. 26/2/03.	10,000 not 100,000 (− indol) (+ clot)	1,000 not 10,000 B.S. 10,000 not 100,000 NR. 10,000 not 100,000 In.	1,000 not 10,000	Virulent B. Pyocyaneus isolated from 1/100 c.c. of effluent.

Description of the Sample.	Number of B. Coli (or gas-forming Coli-like microbes).	B.S.=Bile-salt Glucose Peptone test. N.R. Neutral Red Broth Test. In.=Indol Test. L.P.M.=Lactose Peptone Milk Test.	B. Enteritidis Sporog nes Test.	Remarks.
MAIN WORKS.				
508. Exeter final effluent. 26/3/03.	100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R. 100,000 In.	1,000 not 10,000	
3146A. Exeter final effluent. 5/5/03.	–	100,000 N.R.	100 not 1,000	
563. Exeter final effluent. 23/6 03.	–	100,000 N.R.	100 not 1,000	
566. Exeter final effluent. 24/6/03.	–	100,000 N.R.	100 not 1,000	
569. Exeter final effluent. 25/6/03.	–	100,000 N.R.	100 not 1,000	
3275. Exeter final effluent. 27/10/03.	100,000 (– indol) (+ clot)	100,000 N.R.	100 not 1,000	
3337. Exeter final effluent. 16/12/03.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R.	10 not 100	
3338. Exeter final effluent. 16/12/03.	10,000 not 100,000 (— indol) (+ clot)	10,000 not 100,000 N.R.	100 not 1000,	
666. Exeter final effluent. 24/2/04.	100,000 (+ indol) (+ clot)	100,000 N.R.	1,000 not 10,000,	
3469. Exeter final effluent. 7/6/04.	100,000 (+ indol) (+ clot)	100,000 B.S. 10,000 not 100,000 N.R.	100 not 1,000	
3470. Exeter final effluent. 7/6/04.	100,000 (+ indol) (+ clot)	100,000 B.S. 100,000 N.R.	100 not 1,000	
3528. Exeter final effluent. 2/8/04.	100,000 (+ indol) (+ clot)	100,000 B.S. 100,000 N.R.	1,000 not 10,000	
3544. Exeter final effluent. 18/8/04.	100,000 (+ indol) (+ clot)	100,000 B.S. 100,000 N.R.	100 not 1,000	
3551. Exeter final effluent. 6/10/04.	100,000 (– indol) (– clot)	100,000 B.S. 100,000 N.R.	100 not 1,000	
758. Exeter final effluent. 29/11/04.	100,000 (– indol) (– clot)	100,000 B.S. 100,000 N.R.	1,000 not 10,000	

Effect of Temperature upon the working of the Beds.—The temperature observations have included measurements made on the occasion of each visit, and also a set of measurements taken every few hours over a period of three days. Without experience of severe weather during the observations, it can only be said that the measurements have corroborated what is already known as regards the working of contact beds, in showing that the effluent takes its temperature from that of the sewage and is only slightly affected by the temperature of the atmosphere. The lowest effluent temperature measured was 10° C. (50° F.), and the highest 17° C. (62·6° F.)

LAND.

The effluent from the various filters passes into a main outlet pipe, 3 feet in diameter, by which it is conveyed to a piece of land, 16 acres in extent, about half a mile below the sewage works and bordering on the river. This land has a heavy surface soil, overlying a loose gravel subsoil. It is not underdrained, and the filter effluent, when not delivered in too large a quantity, sinks into it and completely disappears. Up to the present the distribution of effluent on to the land has not been very good, and the area in actual use has not always been large enough to allow of all the liquid percolating into the subsoil, some of it flowing over the surface soil into the river. The distribution is, however, now being much improved (1905). As there is no regular land effluent, our observations have been, for the most part, upon the tanks and filters, and not much attention has been paid to the land.

SUMMARY.

Notwithstanding the fact that it contains a good deal of subsoil water, the sewage is a strong one; while mainly domestic in character, it contains considerable quantities of brewery and tannery refuse. The reasons for its strength are, we think: (1) because it represents the sewage of (virtually) a whole city and not merely of a residential suburb and (2) because it contains manufacturing refuse of an organic character. The suspended solids in the hourly samples averaged 37 parts per 100,000.

Although an estimated volume of six times the dry-weather flow of sewage is passed through the septic tanks, not more than two-and-a-half times this flow is treated on the filters, the excess of tank liquor passing on to a small piece of land about five acres in extent. Having regard to the small area of land available, to the lack of proper distribution of the tank liquor over it, and to the nature of the soil, the treatment of this surplus tank liquor in times of storm cannot be considered altogether satisfactory; at the same time it should be mentioned that the level of the ground is being gradually raised, with the view of increasing its efficiency. But, speaking generally, it seems that sufficient provision has not been made for the treatment of storm water at the works; even with only slight rainfall, storm sewage containing much suspended matter is discharged direct into the river.

There is fair provision for the settlement of grit before the sewage enters the septic tanks, but it would probably have been advantageous if the grit chambers had been made rather larger.

The reduction of the suspended solids of the sewage effected by the septic tanks was 66 per cent. in the case of the hourly samples—a fair percentage settlement—but, notwithstanding this, 12·5 parts of suspended solids still remained in the tank liquor at the time of sampling. That this is a larger quantity than it is desirable to put upon the beds is evidenced by the pronounced loss of capacity of the beds within a period of three years.

The use of only two of the septic tanks at one time, with an average dry-weather "flow through" of 11·5 hours, instead of the whole six tanks, with a correspondingly slower rate of flow, is a departure from the ordinary method of working septic tanks which involves an important principle. Having been unable to make an experimental measurement of the amount of digestion in those large tanks, we cannot offer a definite opinion as to whether this procedure is advisable from the point of view of digestion; it is obvious, however, that it does not reduce to a low figure the quantity of suspended matter passing on to the filters. We think that the drawing off of the sludge at the Exeter main works does not keep pace with its accumulation.

We estimate that the filter beds, after three years' working, have lost about 50 per cent. of their original water capacity. Although we have been unable to make periodical measurements of capacity, we think it not unlikely that the beds will have reached their economic working limit in about two years more, when the question of the partial renewal or washing of the filtering material will require to be considered.

The automatic gear for filling and emptying the filter beds effects a considerable saving in labour, but requires skilled supervision. As a rule, the day service of only two men is needed for these large works, together with the small St. Leonards installation. (On the other hand, more labour might with advantage be given to the

better distribution of the contact bed effluent over the land.) Chiefly owing to the fact that the period of contact of the liquid on the filter beds is a constant one, the automatic gear does not adapt itself to any large variations in the flow of tank liquor, such as result from a heavy storm ; this constitutes a weak point.

During these observations each bed has received on an average about two fillings of septic tank liquor per **24** hours, and, on the basis of the dry weather flow of sewage, they have treated in dry weather a quantity equivalent to **55·5** gallons per cube yard, or **83·3** per square yard, of filter per day. The comparatively rapid rate at which the beds have lost capacity has been due, we think, not so much to the number of fillings having been too great, as to the inadequate settlement of suspended solids from the tank liquor. But even had there been better settlement, it would probably not have been advisable, at all events as regards quality of effluent, to have exceeded this rate of filling with a liquid containing so much organic matter in solution as the Exeter septic tank liquor does in dry weather.

The hourly samples of effluent, collected in summer in practically dry weather, were unsatisfactory in character if judged from the standpoint of a final effluent, *per se*, though they showed a high percentage degree of purification from single contact of the tank liquor. The chance samples, which were for the most part collected in the cooler months of the year, were of better quality, though still indifferent if judged by the same standard. Our observations, therefore, have led us to the conclusion that the treatment of so strong a sewage as that at Exeter by septic tanks followed by single contact filtration, at the rate mentioned, is insufficient to yield an effluent of high class.

Although some smell occasionally arises at the works, the process of sewage purification is carried on without any serious nuisance.

We have made no observations upon the effect of the effluent and of the storm sewage on the water of the river Exe.

In conclusion, we would like to acknowledge our indebtedness to Mr. Donald Cameron, Mr. Goulding, the city surveyor, and also to Mr. W. Mardon, the manager of the works, for much assistance during the observations made in connection with this report.

EXETER SEWAGE WORKS (ST. LEONARDS).

(CITY OF EXETER.)

1. Situation of works - - - - - -	Belle Isle, on the outskirts of Exeter.
2. Method of Treatment - - - - -	Closed septic tanks and single contact beds. (Exeter Septic Tank Syndicate).
3. Population draining to works during observations	1,500 (estimated average).
4. Water supply in gallons per head, and whence obtained - - - - - - - -	30 gallons; from River Exe—a soft water.
5. Number of W.C.'s - - - - - -	600
6. Sewerage system - - - - - - -	Partially separate
7. Average dry weather flow of sewage in gallons per 24 hours - - - - - - -	About 50,000.
8. Gallons of sewage per head per day - - -	33
9. Character of the sewage - - - - -	A weak domestic sewage.
10. Period of observations - - - - - -	October, 1902, to 1906.
11. Age of contact beds - - - - - -	8 years.
12. Amount of storm water treated on filters during observations - - - - - - -	About 3 times the dry weather flow.
13. Total capacity of tanks in gallons - - -	52,000
14. Total area of filters in yards super - - -	400
15. Cubic content of filters in yards cube - -	666
16. Nature of filtering medium - - - - -	4 beds, furnace clinker, 1 bed, coke.
17. Gallons of septic liquor treated per yard super per 24 hours—all filters included - - - -	175
18. Gallons of septic liquor treated per yard cube per 24 hours—all filters included - - - -	105
19. The final effluent is discharged into - - -	The River Exe.

Diagram I.

Diagrams showing flow of Sewage at Exeter (St Leonar

as falling over a Weir 6" wide.

Note:- Over a Weir 6" wide 1·5 inches = a rate of 38,150 gallons per 24 hours.

1·5	inches	= a rate of	38,150	gallons per 24 hours.
2·0	"	= " " "	59,330	" " " "
2·5	"	= " " "	82,512	" " " "
3·0	"	= " " "	109,296	" " " "
3·5	"	= " " "	135,650	" " " "

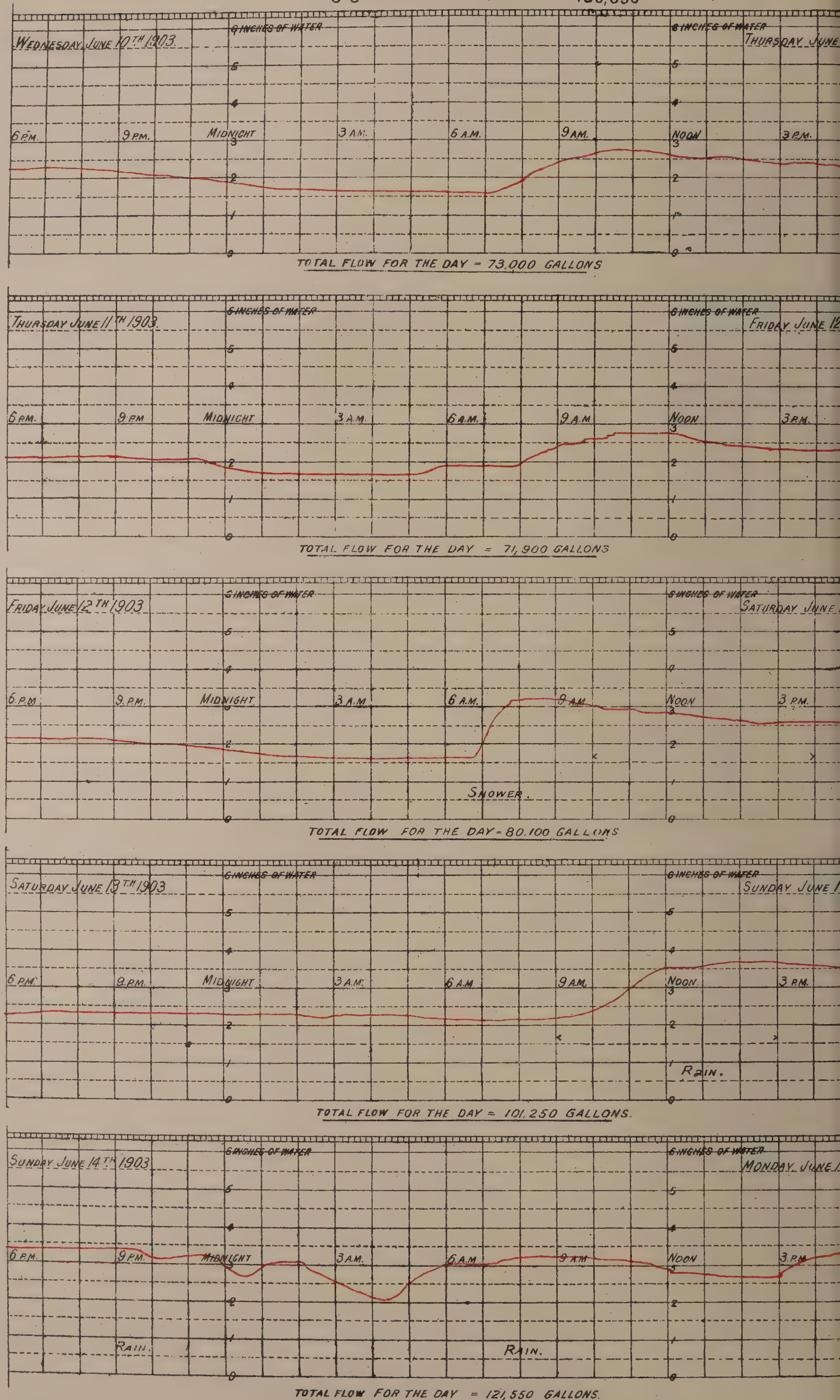
Dry day. Rainfall nil.

Dry day. Rainfall nil.

Rainfall 0·11 inch.

Wet day. Rainfall 0·39 inch.

Wet Day. Rainfall 0·42 inch.



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FLOW OF SEWAGE.

Owing to the combined system of sewerage, the sewage flow is subject to large increases during wet weather, and these increases are accentuated in the outfall sewer, owing to the steep gradient close to the works. Almost at the bottom of this gradient is situated the only overflow on the system, and as it has the effect of protecting the works from any excess above 3 times the dry weather flow, its construction is important.

The main outfall sewer, which is 2 feet in diameter, is here broken for a distance of 4 feet. Between the two disjointed ends, and situated rather below them, is a small tank, at the side of which a submerged 6-inch pipe leads off to the septic tank and filters, at a gradient of one in a thousand. A number of measurements have shown that the maximum rate of flow of sewage through this pipe is between 140,000 and 150,000 gallons per 24 hours When the flow exceeds this rate, therefore, practically the whole of the excess flows across the small tank and is taken by the old 2-feet outfall sewer direct to the river. It may be said, therefore, that not more than 3 times the dry weather flow of 50,000 gallons per 24 hours is treated at the St. Leonards works. In confirmation of this, it may be stated that the greatest number of bed fillings given in any one day during our observations has been about 26; and as the beds hold approximately 5,500 gallons each, practically the same figure of between 140,000 and 150,000 gallons is obtained for the maximum flow treated.

The flow of sewage was measured by means of a recorder on two occasions; once over a period of a week, at the beginning of June, 1903, during rather wet weather, and once over three days at the end of June in the same year, during dry weather. It was also roughly gauged every fortnight during two years (1904-6), when certain special experiments were being carried out. From these measurements the dry weather flow has been estimated to be approximately 50,000 gallons per 24 hours, and the average daily flow for all weathers to be 70,000 gallons.

Except at the time when there is a large increase in the flow owing to the discharge of the Grammar School swimming bath, the flow in dry weather is of an even character, being roughly in the proportion of one volume at night to two in the daytime. This evenness appears to be due chiefly to the presence of a large quantity of subsoil water which enters the sewers and which, during the measurements referred to, apparently accounted for at least half the total flow of sewage in dry weather. The lowest night flow at this time was at the rate of 40,000 gallons per day, while the lowest flow in the approximate gaugings, which have been made every fortnight during the two years ending June, 1906, has been at the rate of 30,000 gallons per 24 hours.

During wet weather the fluctuations of flow in the main outfall sewer are probably large; but as the storm overflow does not allow more than three times the dry weather flow to be delivered to the works, the flow, as it reaches the septic tank, is not subject to very wide variations.

The storm flow at St. Leonards, therefore, is—like the dry weather flow—usually of an even character, although on one occasion, owing to a heavy shower falling upon fairly dry ground, a fluctuation in the proportion of 3½ to 1 within an hour and a half was recorded.

On Diagram I are given some illustrations of the sewage flow at Exeter (St. Leonards).

Unscreened Crude Sewage.—Six sets of hourly samples were examined chemically, *viz.*, two separate series extending over the usual three days in each case. When the first three sets Nos., 546, 549 and 552, were taken, in the early part of June, 1903, there was heavy rain on the first day; hence it was considered necessary to draw a second series a fortnight later, when the weather was dry.

Series 1 gave the following results on analysis :—

	Parts per 1,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - - - - - -	(2·35 to 2·60)	2·49	(3)
Albuminoid Nitrogen - - - - - - - - -	(0·47 to 0·65)	0·55	(3)
Total Organic Nitrogen - - - - - - -	(1·15 to 1·54)	1·39	(3)
Oxidized Nitrogen - - - - - - - - -	(0·0 and 0·0)		(2)
Total Nitrogen - - - - - - - - - -	(3·50 to 4·09)	3·89	(3)
"Oxygen absorbed" at 27° C. (80° F.) *at once* - - -	(1·03 to 1·83)	1·43	(3)
" " " " *in 4 hours* - -	(5·27 to 7·55)	6·53	(3)
Chlorine - - - - - - - - - - - -	(6·20 to 7·12)	6·58	(3)
Solids in Suspension - - - - - - - -	(13·40 to 37·10)	26·70	(3)
Solids by Centrifuge (vols.) - - - - - - -	(60·0 to 133·0)	93·3	(3)
Ratio of Solids in Suspension to Centrifuge Solids -	(1 : 2·9 to 1 : 4·5)	1 : 3·7	(3)

Series 2, consisting of Nos. 570, 573 and 576, gave the following figures :—

	Parts per 1,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen- - - - - - - -	(3·16 and 2·56)	—	(2)
(2) Albuminoid Nitrogen - - - - - - -	(0·25 and 0·64)	—	—
Total Organic Nitrogen- - - - - - - -	(0·79 and 0·94)	—	(2)
Total Nitrogen - - - - - - - - - -	(3·50 to 4·69)	4·05	(3)
"Oxygen absorbed" at 27° C. (80° F.) *at once* - - -	(0 71 to 1·35)	1·08	(3)
" " " " *in 4 hours* - - -	(3·20 to 5·01)	4·35	(3)
Chlorine - - - - - - - - - - - -	(6·20 to 7·00)	6·59	(3)
Solids in Suspension - - - - - - -	(8·80 to 17·80)	13·00	(3)
Solids by Centrifuge - - - - - - - -	(47·0 to 87· 0)	70·3	(3)
Ratio of Solids in Suspension to Centrifuge Solids -	-(1 : 3·8 to 1 : 9· 9)	1 : 6·0	(3)

Excepting in the matter of suspended solids (and consequently also in the figures for "ogygen absorbed"), the two series of sewage samples do not differ much in composition. No. 546 (the first sample of Series 1) contained an excess of solids—mainly mineral—from the washing out of the sewers, and No. 552 (the third sample of Series 1) also probably contained more than the normal proportion, washed out from the catch pit; in this latter case the solids were nearly all organic. On the other hand, the dry-weather samples of Series 2 had probably less than their due proportion of suspended solids, owing to settlement in the sewers during the dry weather.

As bearing on the above point, it may be mentioned here that fortnightly samples of sewage and of tank liquor, extending over 24 hours each, have been drawn from the Exeter (St. Leonards) works, with the view of determining the amount of digestion which goes on in the septic tank there.* The suspended solids in 27 such samples average 26·1 parts per 100,000, while the total nitrogen in 23 of these samples averages 4·16 parts. This total nitrogen is thus almost identical with that in the above two series of hourly samples, while the suspended solids agree with those in the wet-weather series, No. 1.

It may therefore be taken that the Exeter (St. Leonards) sewage does not contain *more than* 26 parts of suspended solids per 100,000, and not more than about 4 parts of nitrogen; hence it is a weak sewage. For the reasons already given, the fluctuations in strength are rather abrupt, although the volume treated only varies within comparatively narrow limits.

The only chance sample of sewage examined was one of storm water, No. 3,273, drawn in October, 1903, during very heavy rain, after the overflow had been working quietly

* See Appendix IV. to Fifth Report of Commission.

for four hours. It contained as much as 132 parts of suspended solids, but 115 of these were inorganic, and it was not so strong organically as the hourly samples. On the day of analysis it had a clean, faint, earthy smell, though it failed to withstand incubation.

Bacteriological Notes:—Six samples of crude sewage and one sample of storm water were examined bacteriologically. With one exception they all yielded positive results with 1/100,000 c.c. (100,000 per c.c.) with the neutral red broth test. The number of spores of B. enteritidis sporogenes varied from 100 to 1,000 per c.c.

Description of the Sample.	Number of B. Coli (or gas-forming coli-like Microbes).	B.S. = Bile-salt glucose peptone test. N.R. = Neutral red broth test. In = Indol test. L.P.M. = Lactose peptone milk test.	B. enteritidis sporogenes test.	Remarks.
ST. LEONARDS.				
546. Exeter crude sewage, 9/6/03.	—	100,000 N.R.	100 not 1,000	
549. Exeter crude sewage, 10/6/03.	—	100,000 N.R.	100 not 1,000	
552. Exeter crude sewage, 11/6/03.	—	100,000 N.R.	100 not 1,000	
570. Exeter crude sewage, 29/6/03.	—	10,000 not 100,000 N.R.	1,000 not 10,000	
573. Exeter crude sewage, 1/7/03.	—	100,000 N.R.	100 not 1,000	
576. Exeter crude sewage, 2/7/03.	—	100,000 N.R.	1,000 not 10,000	
[3273. Exeter storm over-flow liquid, 27/10/03.]	100,000 (– indol) (– clot)	100,000 N.R.	100 not 1,000	

GRIT CHAMBER.

The sewage from the main sewer flows through a small grit chamber, which is cleaned out every week and also after storms, the matter removed on all occasions being chiefly grit.

SEPTIC TANK.

Number - - - - - - -	1.
Size - - - - - - - -	66 feet by 18 feet.
Average depth of water - - - - -	7 feet.
Capacity - - - - - - -	52,000 gallons.

Construction.—The septic tank is constructed of cement concrete throughout, and is covered by a concrete arch. At its inlet end it contains two smaller tanks, each 7′ long by 8′ 6″ wide, the walls of which are carried up 8′ 9″ from the bottom to within one foot of the water level in the tank. Each of the two inlet pipes to the tank delivers the sewage below the water level into one of these smaller tanks, which therefore serve as preliminary grit chambers.

After having deposited some of its suspended matter in one of the smaller tanks, the sewage flows upwards over the retaining wall and through the rest of the tank, which has no further partition except a 22″ scum-board placed across the tank, rather more than half-way towards the outlet end. It issues from the tank through a slotted pipe extending the whole way across the outlet end of the tank, and placed 16″ below the level of the water.

Flow Through.—With an average daily flow of 70,000 gallons per 24 hours, the flow through the tank would be once in 17·8 hours, at the rate of ·63″ per minute.

With a maximum flow of 145,000 gallons per 24 hours, the flow through would be once in 8·6 hours, at the rate of 1·30″ per minute.

* *See* Appendix IV. to Fifth Report of Commission.

Working.—The flow of sewage through the tank is a continuous one. Except at those times when it is necessary to remove sludge from the tank, it is never stopped.

Sludging.—From August 1896, when it was first brought into use, to May 1902, the tank worked continuously without the removal of any sludge. Towards this latter date, the amount of suspended matter in the tank liquor began to exceed the limit which it was thought advisable to put upon the contact beds. By means of a pump, therefore, a considerable but unknown quantity of sludge was removed and used for the purpose of inoculating the large tanks constructed for the main Exeter scheme, which were just then being brought into action.

The tank then ran for a further period of two years till April 9th, 1904, without being touched. As no measurement of the sludge removed had been made in 1902, it was impossible to obtain figures for the amount of digestion without completely emptying the tank; and as it appeared both from the suspended matter issuing in the tank liquor and also from trials in the man-holes that the tank contained a considerable amount of sludge, we obtained permission to empty the tank completely, and on April 9th, 1904, the work of emptying was begun.

On removing the supernatant liquid by pumping, the tank was found to contain an average of about 4 feet of thick sludge throughout, more than half the total capacity of the tank being thus taken up by the sludge. A sample was taken of the bottom sludge from the lower end of the tank at this time and was examined ten days later.

As there were no sludge valves to the tank, the sludge had to be removed by means of a pump, let down through one of the cover-holes. A 7″ centrifugal pump was first tried, and some of the thinner sludge lying on the top (as well as some of the thicker sludge, which was made thinner by allowing the sewage to flow into the tank and then stirring up) was removed by this means and delivered into a lagoon made of fine clinker.

The necessity, however, of mixing sewage with the sludge, in order to make it thin enough to pump, resulted in a very large increase in its volume, which not only made the operation slow and difficult, owing to the large quantity of water to be got rid of, but, in some measure, as it appears to us, undid the work of the tank by converting a thick spadeable sludge into a thin liquid one. After a short time, however, the centrifugal pump was removed and replaced by a rubber valve pump, and the thick sludge was then lifted into slop-carts and buried in a deep deposit of fine clinker screenings on the works.

The operation was completed on June 14th, having taken rather over 2 months, though probably, if a valve pump had been used at the start, it would have required much less time. It was conducted practically without nuisance, the sludge having only a slight smell.

Examination of the Sludge.—A portion of the sludge shaken up with water gave an upper layer containing much fibre, mostly about ·5 millimetre in length, but up to a very large size; also brown masses up to 1 millimetre in length, together with a considerable quantity of fine siliceous matter (averaging ·05 millimetre). The sludge contained, besides, large pieces of paper up to 25 or 50 millimetres square, and long fibres (probably fine string) up to 50 millimetres in length. The quickly settling sediment consisted almost exclusively of grit, mostly about ·2 to ·3 millimetre long, but up to ·9 millimetre.

The sludge consisted of :—

Moisture	75·39 per cent.	(*a*) "Cellulose" by alkali acid, and ether	1·96 per cent.
Volatile Matter	5·95 „	(*b*) "Cellulose" Do. after permanganate	1·03 „
Non-Volatile Matter	18·66 „	Grit from estimation (*a*)	11·33 „
		Grit from estimation (*b*)	9·10 „
	100·0		

The undried sludge gave the following figures :—

———	Parts per 100,000.		Per cent.
	(a)	(b)	
* Total Nitrogen	493·0	492·0	0·49
"Oxygen absorbed" from Permanganate at 27°C. (80°F.) *in* 4 *hours*	3371·0		3·37

Gas Evolution Experiment.—6·7 grams of the wet sludge were mixed with 570 c.c. of distilled water (containing 6·3 c.c. of oxygen per litre) and *kept* under anaerobic conditions. After standing for nearly a year and a half, only a trace of gas, if any, had been evolved, this apparently showing that the bulk of the bottom sludge, at all events, had already undergone in the tank all the gaseous decomposition that was ever likely to occur under practical conditions of working.

Septic Tank Liquor.—Two different series of hourly samples of septic tank liquor, each extending over three days, were drawn at the same time and under the same conditions as the hourly samples of sewage. Excepting in the matter of suspended solids, of which the first series contained rather more than the second, there was practically no difference between these two series, and they may therefore be grouped together here. The numbers of the samples were :—Series 1, Nos. 547, 550 and 553; Series 2 :—Nos. 571, 574 and 577. They gave the following results on analysis :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(2·64 to 3·73)	3·70	(6)
Albuminoid Nitrogen	(0·27 to 0·40)	0·34	(6)
Total Organic Nitrogen	(0·62 to 0·85)	0·68	(5)
Total Nitrogen	(3·26 to 4·35)	3·98	(5)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(0·68 to 1·48)	1·01	(6)
" " " " *in* 4 *hours*	(2·84 to 4·79)	3·59	(6)
Chlorine	(5·60 to 8·20)	6·69	(6)
Solids in Suspension	(3·30 to 11·60)	8·23	(6)
Solids by Centrifuge (vols.)	(12·0 to 43·0)	31·0	(6)
Ratio of Solids in Suspension to Centrifuge Solids	(1 : 3·4 to 1 : 6·3)	1 : 4·5	(6)

The septic tank liquor is, like the sewage, very weak, containing only about 4 parts of total nitrogen and about 7 parts of suspended solids per 100,000.

Comparing the six sets of hourly samples of septic tank liquor with the corresponding sets of sewage, we get the following reduction in figures :—

Total Nitrogen	No reduction.
"Oxygen absorbed" *in* 4 *hours*	34 per cent. reduction.
Suspended Solids	65 " "

A better idea is, however, obtained by contrasting the 24 hours' samples, drawn fortnightly for nearly a year past, starting with a clean septic tank :—

———	Sewage.	Number of Estimations.	Septic Tank Liquor.	Number of Estimations.	Reduction.
Total Nitrogen	4·16	(23)	3·71	(21)	12 per cent.
"Oxygen absorbed" *in* 4 *hours*	7·05	(22)	3·64	(22)	48 "
Solids in Suspension	26·10	(27)	8·40	(25)	68 "

* Equal to 2·0 per cent. Nitrogen in the *dry* sludge.

Bacteriological Notes:—Six samples were examined bacteriologically. They all yielded positive results with 1/100,000 c.c. (100,000 per c.c.) with the neutral red broth test. As regards the B. enteritidis sporogenes test, one sample contained 10, four samples 100, and one sample 1,000 spores of this anaerobe per c.c.

Description of the Sample.	Number of B. Coli (or gas-forming coli-like microbes).	B.S.=Bile-salt glucose peptone test. N.R.=Neutral red broth test. In.=Indol Test. L.P.M.=Lactose peptone milk test.	B. Enteritidis Sporogenes test.	Remarks
ST. LEONARD'S.				
547. Exeter septic tank liquor, 9/6/03	—	100,000 N.R.	100 not 1,000	
550. Exeter septic tank liquor, 10/6/03	—	100,000 N.R.	10 not 100	
553. Exeter septic tank liquor, 11/6/03	—	100,000 N.R.	100 not 1,000	
571. Exeter septic tank liquor, 30/6/03	—	100,000 N.R.	1,000 not 10,000	
574. Exeter septic tank liquor, 1/7/03	—	100,000 N.R.	100 not 1,000	
577. Exeter septic tank liquor, 2/7/03	—	100,000 N.R.	100 not 1,000	

FILTERS.

Number - - - -	5.
Size of each - - - -	4 filters, 36 feet by 20 feet. 1 filter, about 30 feet by 24 feet.
Area of each - - - -	720 square feet.
Total area - - - -	400 square yards.
Depth of material - - -	5 feet.
Cubic content of each - -	3,600 cube feet.
Total cubic content - -	666 cube yards.
Material - - - - -	No. 1 bed, clinker of ½″ to ⅛″ diameter, with rough shingle and gravel laid over the drains. No. 2 bed, 1 foot clinker of 1″ diameter, laid over the drains, and the rest ⅓″ diameter. No. 3 bed, 1 foot of coke breeze 1″ diameter, laid over the drains, and the rest ½″ diameter. No. 4 bed, 2 feet of clinker, 1″ diameter. laid on the drains, and the rest ½″ diameter. No. 5 bed, 1 foot of clinker, 1″ diameter. laid over the drains, and the rest ½″ to ⅛″ diameter.
Construction	Cement and concrete throughout.
Distribution	One 9″ half pipe laid on the surface of the material and fed directly from the valve.

Underdraining.—Ten lines of 2″ agricultural pipes connecting to a main drain, which delivers to the discharge valve.

Working.—The filters are filled and emptied by means of the automatic gear designed by the Septic Tank Company, Limited. As soon as a filter is full, a small quantity of filtered effluent overflows from it into the bucket of the previous filter to be filled, and which is therefore standing full. The fall of this bucket shuts the admission valve of the filter which has just filled, and opens the discharge valve of the full filter, shutting at the same time the discharge valve of a third filter and opening its admission valve.

As there are only four sets of gear, only four filters can be used as a working set, and there is therefore always one filter at rest. The usual plan is to rest each filter in turn for two days. The resting filter is cut out or brought in by hand.

It will be seen that only one filter can fill at a time by this arrangement, and that the time of filling and length of contact depend upon the rate of flow of sewage. It should be said, however, that during the observations the beds have generally filled in about an hour and have therefore given a contact of one hour.

At the commencement of the observations, in 1903, the average number of bed fillings per day was approximately ten, while at the end of the observations it had increased to an average of about fifteen. This increase has, no doubt, been partly due to the loss of capacity and partly to the increased flow of sewage.

During the observations the beds have been filled on the average between two and three times each day.

Age of Beds.—The beds were first used in August, 1896. They have undergone no alteration since they were first constructed.

Capacity.—The original empty tank capacity of the five beds was 112,500 gallons, and the original water capacity, therefore, assuming the material to have occupied half the capacity of the beds when new, was 56,250 gallons.

The first measurement of capacity, made in June, 1903, by taking three beds as typical, gave a total water capacity of approximately 27,000 gallons, *i.e.* 48 per cent. of the original water capacity, and 24 per cent. of the original empty tank capacity. Although they had lost, therefore, half their capacity, the beds were still in good working order after nearly seven years of constant use, at an estimated average rate of working of about two fillings per day for each bed.

Owing to the increase in the flow of sewage and in the rate of filtration (four fillings for each working bed per day), it seemed likely that a further loss of capacity would take place, and a second measurement, made in September, 1905, on bed No. 2, taken as typical, gave a total water capacity of only 16,580 gallons, *i.e.* 29·4 per cent of the original water capacity, or 14·7 per cent. of the original empty tank capacity. It appears, therefore, from this measurement, that the capacity of the beds is now considerably reduced. The appearance also of the material corroborates this; but as there are no signs of soddenness, and as the tank liquor sinks rapidly into the beds, it is probable that they will continue to work effectively for some little time. As has been shown, however, the capacity now is less than one-third of the original water capacity when the beds were new.

Amount of Tank Liquor Treated by the Filters.—On the basis of an average daily flow of 70,000 gallons per twenty-four hours, the amount treated by the filters is as follows:—

Per square yard per 24 hours - - -	175 gallons.
Per cube yard per 24 hours - - -	105 gallons.

Effluents.—Six sets of hourly samples (in two series of three each), drawn at the same time as the hourly samples of sewage and tank liquor, were examined chemically. The second series was better than the first, so the results may be given separately :—

Series 1, drawn in June, partly in wet weather, (Nos. 548, 551 and 554) :—

	Parts per 100,000	Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - - -	(1·03 to 1·64 approx.)	1·32	(3)
Albuminoid Nitrogen - - - - - - -	(0·16 and 0·18)		(2)
Oxidized Nitrogen - - - - -	(1·06 approx. to 1·30 approx.)	1·20 ap.	(3)
Total Nitrogen - - - - - - - -	(2·18 to 2·70)	2·48	(3)
"Oxygen absorbed" at 27° C. (80° F.) *at once* - -	(0.24 to 0·92)	0·56	(3)
,, ,, ,, ,, ,, *in 4 hours* -	(1·66 to 2·14)	1·85	(3)
Solids in suspension - - - - - - -	(2·12 to 3·08)	2·60	(3)
Solids by centrifuge (vols.) - - - - -	(21·0 to 37·0)	30·0	(3)
Ratio of Solids in suspension to Centrifuge solids -	(1 : 9·9 to 1: 14·2)	1 : 11·4	(3)
Incubator Test (Scudder) - - - - - - - - - -		3+	(3)
Incubator Test (by Smell) - - - - - - - - -		3+	(3)
Smell when drawn - - - - - - - - - -		2– 1+	(3)
Smell when analysed - - - - - - - - - -		2– 1+	(3)

Series 2, drawn in June, in dry weather (Nos. 572, 575, 578), gave :—

	Parts per 100,000	Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - - - -	(0·89 to 1·18)	1·00	(3)
Albuminoid Nitrogen - - - - - - - - - -			
Oxidized Nitrogen - - - - - - - -	(1·33 to 1·61)	1·49	(3)
Total Nitrogen - - - - - - - -	(2·42 to 2·74)	2·58	(3)
"Oxygen absorbed" at 27° C. (80° F.) *at once* - - -	(0·11 to 0·16)	0·14	(3)
,, ,, ,, ,, ,, *in 4 hours* - -	(0·47 to 1·06)	0·85	(3)
Chlorine - - - - - - - - - - -	(7·0 to 7·02)	7·01	(3)
Solids in Suspension - - - - - - -	(0·58 to 1·28)	0·90	(3)
Solids by Centrifuge (vols.) - - - - - -	(12·0 to 12·5)	12·2	(3)
Ratio of Solids in Suspension to Centrifuge Solids - -	(1 : 9·5 to 1 : 20·7)	1 : 15·0	(3)
Incubator Test (Scudder) - - - - - - - - -		3+	(3)
Incubator Test (by Smell) - - - - - - - -		3+	(3)
Smell when drawn - - - - - - - - - -		3—	(3)
Smell when analysed - - - - - - - - - -		3+	(3)

Each of the foregoing six hourly sets of effluent was made up of equal volumes from the middle flow of all the discharges from the beds during the 24 hours, these discharges varying in number between twelve and sixteen per day. In appearance the samples of the first (wet weather) series were slightly turbid, those of the second (dry weather) series being fairly clear. It will be noted that the suspended solids averaged 2·6 parts in Series 1 and only 0·9 part in Series 2.

Most of the samples had a slight sewage smell when drawn and two of them retained this on the day of analysis, but they were all well nitrated (containing fully half their nitrogen in the form of nitrate), and they all withstood the incubator test without using

up much nitrate (approx. 0·2 to 0·5 part) in the process. Although the samples of the second series were appreciably better in quality than those of the first, the whole six sets, which were drawn in the month of June, may be regarded as fair (*c.f.* Notes on Chance Samples, below).

Chance Effluents.—The six chance samples of effluent examined chemically, Nos. 3145, 615, 3274, 3339, 665 and 3620, were with one exception drawn between October and February (the hourly samples were taken at midsummer). These chance samples were all drawn at or about mid-flow, between the hours of 9.45 a.m. and 3.30 p.m., partly in dry and partly in wet weather. They gave the following results on analysis :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(0·02 to 1·59)	0·55	(6)
Albuminoid Nitrogen	(0·04 to 0·27)	0·11	(5)
Oxidized Nitrogen	(0·60 approx. to 2·66)	1·69 ap.	(6)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(0·10 to 0·44)	0·19	(6)
,, ,, ,, ,, ,, *in 4 hours*	(0·45 to 1·91)	1·08	(6)
Dissolved Oxygen taken up in 24 hours at 18° C.	(0·0 to 1·44)	0·62 ap.	(3)
Chlorine	(4·66 to 5·80)	5·19	(3)
Solids by Centrifuge (vols.)	(1·8 to 15·0)	8·1	(6)
Incubator Test (Scudder)		4+1—	(5)
Incubator Test (by smell)		5+1 (?)	(6)
Smell when drawn		5+	(5)
Smell when analysed		6+	(6)
Oxygen in solution (c.c. per litre)	(0·2 to 5·0)	1·7 c.c.	(4)

The above six samples were for the most part very clear, with but little suspended solid (about 0·6 part per 100,000, on the average, as judged by the centrifuge volumes). Excepting possibly the last sample, No. 3620, they all had a clean smell, both when drawn and when analysed, and withstood the incubator test. Four out of the six may be described as very good effluents, with much the greater part of their nitrogen in the oxidized state. Sample No. 3339 was specially good, in fact, an effluent of high class. It was drawn on a dry day, after wet weather, from a bed which had rested for 4 hours since the previous filling, the flow being still rather over the normal. But the tank liquor to which this effluent corresponded must have been weak, the effluent containing only 4·7 parts of chlorine. No. 665 was also excellent; it took up no dissolved oxygen in 24 hours.

Speaking generally, the chance samples of effluent were much better than the hourly samples, although, as already seen, the latter were fair in quality. The reason for this difference no doubt was that the hourly samples were drawn in summer, when the sewage was stronger.

As compared respectively with the six sets of hourly samples of sewage and of tank liquor, the six hourly and the six chance samples of effluent show the following reduction in figures :—

Hourly Samples of Effluent.	Calculated on :—	
	Sewage.	Septic Tank Liquor.
Total Nitrogen	36 per cent. reduction.	36 per cent. reduction.
"Oxygen absorbed" *in 4 hours*	75 ,,	62 ,,
Solids in suspension	91 ,,	79 ,,

Chance Samples of Effluent.	Calculated on :—	
	Sewage.	Septic Tank Liquor.
Albuminoid Nitrogen - - - - - - - -	79 per cent. reduction.	68 per cent. reduction.
"Oxygen absorbed" *in* 4 *hours* - - - - - -	80 ,,	70 ,,
Solids in suspension - - - - - - - -	97 per cent. approx.	93 per cent. approx.

Bacteriological Notes.—Twelve samples were examined bacteriologically. Most of the samples yielded positive results with the B. coli test and presumptive tests for B. coli with 1/100,000 c.c. (100,000 per c.c.). Two samples, however, yielded negative results with 1/10,000 c.c. and 1/1000 c.c. (Nos. 3339 and 665, respectively). These two samples yielded negative results with 1/10 c.c. (less than 10 per c.c.) with the B. enteritidis sporogenes test. The other samples contained from 10 to 100 spores of this anaerobe per c.c.

Description of the Sample.	Number of B. Coli (or gas-forming Coli-like Microbes).	B.S. = Bile-salt glucose peptone test. N.R. = Neutral red broth test. In = Indol test. L.P.M. = Lactose peptone milk test.	B. enteritidis sporogenes test.	Remarks.
St. Leonards.				
3145. Exeter final effluent, 5/5/03.	—	100,000 N.R.	10 not 100	
548. Exeter final effluent, 9/6/03.	—	100,000 N.R.	10 not 100	
551. Exeter final effluent, 10/6/03.	—	100,000 N.R.	10 not 100	
554. Exeter final effluent, 11/6/03.	—	100,000 N.R.	10 not 100	
572. Exeter final effluent, 30/6/03.	—	100,000 N.R.	100 not 1,000	
575. Exeter final effluent, 1/7/03.	—	100,000 N.R.	10 not 100	
578. Exeter final effluent, 2/7/03.	—	100,000 N.R.	100 not 1,000	
615. Exeter final effluent, 6/10/03.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R.	10 not 100	
3274. Exeter final effluent, 27/10/03.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R.	100 not 1,000	
3339. Exeter final effluent, 16/12/03.	1,000 not 10,000 (– indol) (– clot)	1,000 not 100,000 N.R.	1 not 10	
665. Exeter final effluent, 24/2/04.	100 not 1,000 (+ indol) (+ clot)	100 not 1,000 N.R.	1 not 10	
3620. Exeter final effluent, 13/2/05.	100,000 (+ indol) (+ clot)	100,000 B.S. 100,000 N.R.	10 not 100	

Effect of Temperature upon the Beds.—The observations on temperature included measurements made on the occasion of each visit to the works, and two 3-day sets of measurements made every few hours.

As there was no severely cold weather during the observations, little can be said in regard to the effect of a low temperature upon the working of the beds; but as the lowest

effluent temperature recorded in ordinary frosty weather was 9° C. (48° F.), it may probably be inferred that the atmospheric temperature has only a slight effect upon the temperature of the sewage during its process of treatment.

SUMMARY.

The sewage is a weak domestic one, containing about 4 parts of nitrogen and not more than about 26 parts of suspended solids per 100,000, its dilute character being due to the inclusion of a large quantity of subsoil water, and also to the fact that the district sewered is a purely residential one.

Not more than three times the dry-weather flow is treated at the works in times of storm, even when the sewage is greatly diluted; hence, in wet weather, the septic tank is only called upon to treat comparatively small quantities of storm water impurities. With regard to the sewage flowing into the septic tank, however, it has to be borne in mind that, owing to the outside grit-chamber being small, the tank is not well protected against the ingress of heavy suspended matters, mineral and other.

The tank effects a fair settlement of the suspended solids of the sewage. In June, 1903, when it must have been more than one-third full of sludge, the suspended solids issuing from the tank amounted to about 8 parts per 100,000; and this is also the average figure for suspended solids in the tank liquor for the past year (1904–5), since the tank was emptied and re-started.

In Appendix IV to the Fifth Report of the Commission, the results are given of the actual digestion of sewage matters effected in the tank, over a period of two years. But it may be useful to point out here that the tank ran from August, 1896, to May, 1902, without having anything removed from it. A considerable quantity of the sludge was then pumped into the large septic tanks of the New Works, with the object of seeding them, but we have no means of ascertaining what this quantity was. The tank then ran again until April, 1904, when it was found to be half full of sludge.

The filter beds—four of clinker and one of coke—have been in constant use since August, 1896, working at an estimated rate of 2½ fillings per twenty-four hours. In June, 1903, *i.e.*, after nearly seven years' work, these filters had a capacity equal to 48 per cent. of the original water capacity, or 24 per cent. of the original empty tank capacity; and in September, 1905, after rather more than nine years work, the capacity had been reduced to 29·4 per cent. of the original water capacity, or 14·7 per cent. of the empty tank capacity.

Judging from the length of time that the filters have lasted, and from the fact that the materials composing them have not been much disintegrated, the coke and clinker have evidently been well suited, both in quality and in size, for the treatment of the dilute septic tank liquor at St. Leonards.

The automatic gear for filling and emptying the filter beds has worked very well indeed throughout these observations, and has required but little attention to keep it in order; this, we think, is due to the simple method of overflow by which the gear is actuated. By this action the length of the period of contact on the filters is dependent upon the rate of flow of the tank liquor at the time; and, although there are arguments which may be advanced against this, the balance of evidence appears to us to be in its favour, given a sufficient filtering area. During the first flush of storm water after a period of dry weather, the filter beds would no doubt be heavily taxed under this system, but otherwise increase of flow is, as a rule, coincident with increased dilution as regards organic matter.

During the observations the filters have received on an average 4 fillings each per twenty-four hours, equal to 105 gallons per cube yard per twenty-four hours for the whole filtering area. Even having regard to the weak character of the septic tank liquor, this is probably as large a volume as they could be called upon to treat without danger of rapid loss of capacity.

The hourly samples of effluent, which were collected at midsummer, were of moderate quality, while the chance samples, nearly all of which were taken between October and February, when sewage is naturally more dilute, were for the most part of good quality. Septic tank treatment, followed by single contact, can therefore be made to give satisfactory results in the case of a *weak* sewage.

We have always, on our visits to the St. Leonards' Works, found them to be practically free from nuisance. This, we think, is to be ascribed to the fact that both the septic tank and the channels are covered in, and also to the fact of the tank liquor being a dilute one from domestic sewage.

We desire to express our thanks to Mr. Donald Cameron, C.E., Mr. Goulding, City Engineer, and Mr. Marden, Manager of the Sewage Works, for much help in connection with our work at Exeter.

GUILDFORD SEWAGE WORKS.

(CORPORATION OF GUILDFORD.)

1.	Situation of works - - - -	About one and a quarter miles from the centre of the town.
2.	Methods of treatment - - - -	(1) Chemical precipitation followed by land; (2) open septic tank and double contact filtration, followed by continuous filtration through shallow percolating filters.
3.	Population draining to works during observations - - - - - - -	16,000 (average).
4.	Water supply in gallons per head and whence obtained - - - - - - -	31·4; from shallow wells in the chalk—a hard water.
5.	Number of W.C.'s - - - - - -	3,700, approximately.
6.	Sewerage system - - - - - -	Partially separate.
7.	Average dry weather flow of sewage in gallons per 24 hours - - - - - -	400,000.
8.	Gallons of sewage per head per day - -	25
9.	Character of the sewage - - - -	A strong domestic sewage, containing a large proportion (about one-fourth) of brewery refuse and other trade waste.
10.	Period of observations - - - - -	July, 1902 to November, 1904.
11.	Age of primary beds - - - - -	Two years.
	,, secondary ,, - - - - -	Two years.
	,, tertiary ,, - - - - -	Constructed during the observations.
12.	Amount of storm water treated on filters during observations - - - - -	The *volume* treated on the contact beds is constant.
13.	Total capacity of tanks in gallons - - -	(1) Precipitation tanks, 264,000; Septic tank, 153,000.
14.	Total area of filters in yards super - -	4,759·6.
15.	Total cubic content of filters in yards cube -	3,969·7.
16.	Nature of filtering material - - - -	(1) Primary beds:—2 Beds, clinker; 3 beds, burnt ballast. (2) Secondary beds:—2 Beds, Clinker; 3 beds, burnt ballast. (3) Tertiary beds:—No. 1, Fine burnt ballast; Nos. 2 and 3, fine clinker and sand.
17.	Gallons of septic tank liquor treated per yard super per 24 hours on double contact beds	18·8.
18.	Gallons of septic tank liquor treated per yard cube per 24 hours on double contact beds;	22·7.
19.	The final effluent is discharged into - -	The river Wey, which joins the Thames at Weybridge.

Diagram J.

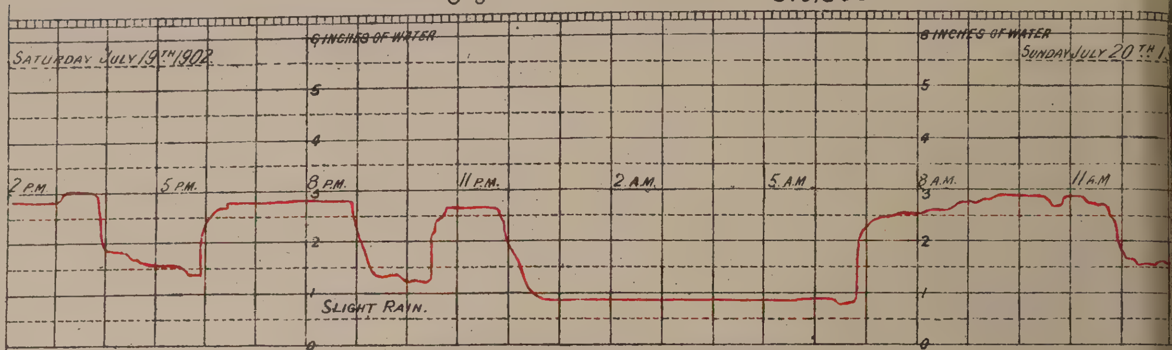
Diagrams showing flow of Sewage at Guildford as falling over a Weir 36" wide.

Note:- Over a Weir 36" wide

0·75 inch	=	a rate of 80,928 gallons per 24 hours.
1·50 inches	=	" " 238,520 " " " "
2·0 "	=	" " 354,240 " " " "
2·5 "	=	" " 495,360 " " " "
3·0 "	=	" " 650,880 " " " "
3·5 "	=	" " 819,360 " " " "

Rainfall 0·03 inch.

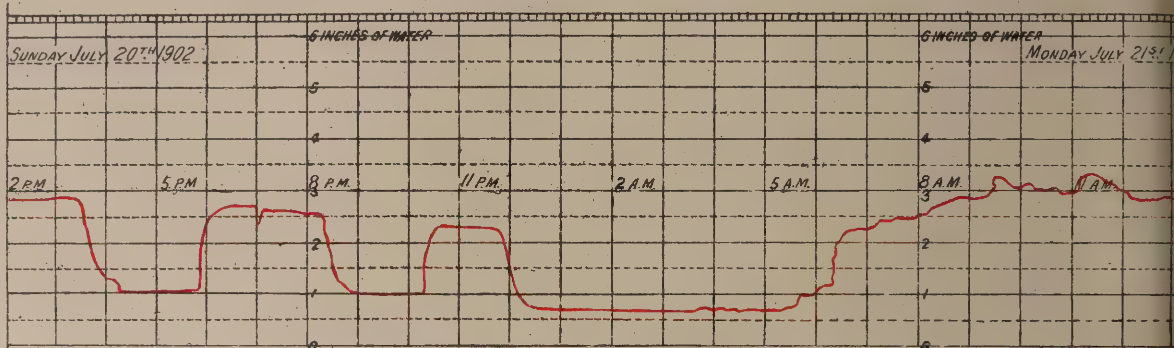
Dry weather flow.



Total flow for the day = 364,000 gallons.

Rainfall Nil.

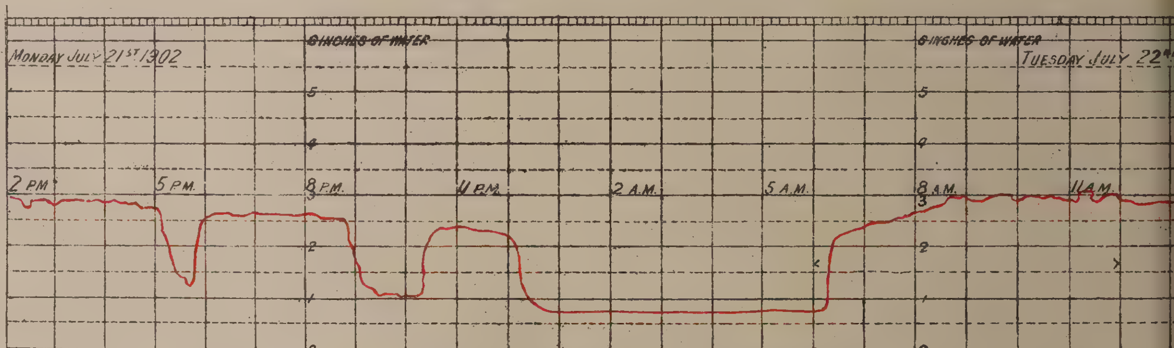
Dry weather flow.



Total flow for the day = 367,800 gallons

Rainfall 0·01 inch.

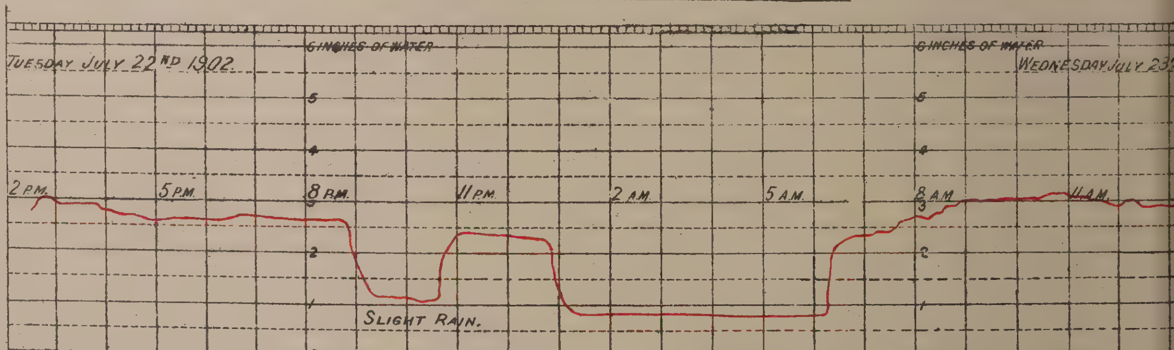
Dry weather flow.



Total flow for the day = 410,200 gallons

Rainfall 0·02 inch.

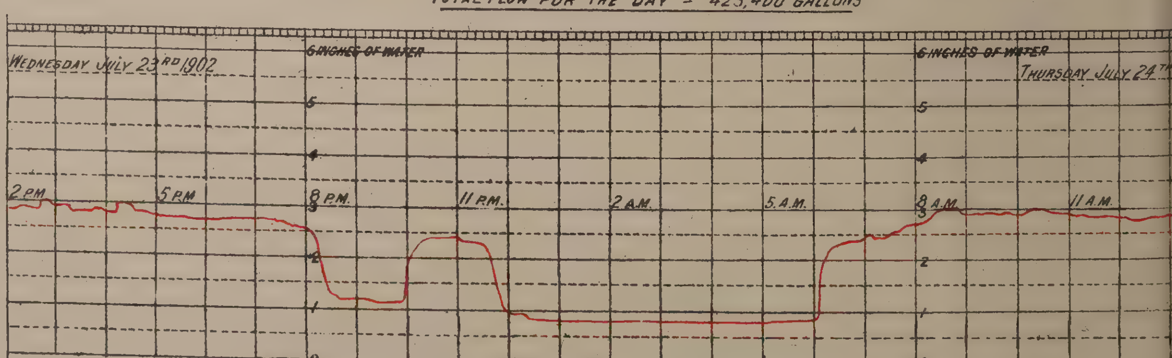
Dry weather flow.



Total flow for the day = 423,400 gallons

Rainfall Nil.

Dry weather flow.



Total flow for the day = 420,600 gallons

Note. The regular variations in the Guildford sewage flow are due to the fact that part of the sewage is pumped.

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FLOW OF SEWAGE.

We were fortunate in having very favourable weather for our gaugings of the sewage flow at Guildford and the measurements were therefore satisfactory. The gauging lasted for seven days (July 17th to 23rd, 1902) in perfectly dry weather, and gave the average flow per day as 400,000 gallons. This figure, therefore, has been taken as the dry weather flow.

The highest day's flow, 423,600 gallons, occurred on the Tuesday of the week, and the lowest, 364,000 gallons, on the Saturday. The highest rate of flow, 785,000 gallons per 24 hours, came down at 11.30 a.m. on the Monday, and the lowest rate of flow, 63,500 gallons per 24 hours, between the hours of 12.30 midnight and 5.30 a.m. each night. In dry weather, about six-sevenths of the total flow comes down during the 16 hours of the day, and one-seventh during the 8 hours of the night. The chief reason for this great difference is that the pumps on the low level system always cease working from midnight to 6 a.m. in dry weather; and this is also the reason for the large variations in flow which occur in the evening and early morning.

Some storm-water finds its way into the low level sewerage system. So far as we are able to judge, however, the quantity is not great, excepting during periods of heavy rain or when the river is much swollen. We have made no gaugings of the flow at such times, but we understand that it rarely exceeds three times the dry weather flow.

In regard to subsoil water, our records have led us to believe that a moderate quantity of subsoil water (probably about one-fifth of the total flow of sewage in dry weather) enters the sewers; this would include leakage from taps, which is no doubt considerable.

The gauging results may be summarised as follows :—

Dry weather flow - - -	400,000	gallons per 24 hours.
Highest day's flow (dry weather) -	423,600	,, ,,
Lowest day's flow (dry weather) -	364,000	,, ,,
Highest rate of flow (dry weather) -	785,000	,, ,,
Lowest rate of flow (dry weather) -	63,500	,, ,,

On Diagram J. are given some illustrations of the sewage flow at Guildford.

Screens and Detritus Tanks.—The whole of the sewage passes through a Smith's Patent Sewage Screen (John Smith, Carshalton) before it flows to the septic or precipitation tanks. The screen has a $\frac{1}{4}$-inch mesh, and is rotated and cleaned automatically by a water-wheel placed in the sewage flow.

During the greater part of the observations, a wide woven wire band constituted the actual screen, but towards the end this wore out, and was replaced by a band of flexible steel shutters, perforated with $\frac{1}{4}$-inch circular holes. The screen appears to us to fulfil its purpose with the Guildford sewage. A considerable nuisance arises from the screenings and also from the water-wheel actuating the screen.

Crude Sewage.—Six samples were examined, viz., five sets of hourly and one chance sample. The first three sets of *hourly* samples, Nos. 3014, 3017 and 3021, extended over 72, 48 and 48 hours respectively, in July, 1902, and the second two sets, Nos. 752 and 756, over 24 hours each, in November, 1904. The July samples were kept in ice until they were despatched to the laboratory. About 0·08″ of rain fell in the night when No. 752 was being drawn, but otherwise the weather was dry throughout. The following figures were obtained from the five hourly samples :—

Parts per 100,000.		Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - - - -	(6·56 to 8·01)	7·39	(5)
Albuminoid Nitrogen - - - - - - -	(1·57 to 2·08)	1.91	(5)
Total Organic Nitrogen - - - - - -	(3·48 to 4·32)	3·95	(5)
Oxidized Nitrogen - - - - - - - -	(0·0)	0·0	(5)
Total Nitrogen - - - - - - - -	(10·90 to 11·98)	11·34	(5)
"Oxygen absorbed" at 27° C. (80° F.) *at once* - - -	(4·43 to 5·58)	4·96	(5)
,, ,, ,, ,, *in 4 hours* - -	(20·59 to 24·29)	21·96	(5)
Chlorine - - - - - - - - - -	(9·98 to 11·50)	11·02	(5)
Solids in Suspension - - - - - - - -	(36·6 to 54·3)	42·1	(5)
Solids by Centrifuge (vols.) - - - - - -	(286 to 387)	331·0	(5)
Ratio of Solids in Suspension to Centrifuge Solids -	(1 : 6·8 to 1 : 9·1)	1 : 7·6	(5)
"Cellulose" (by alkali, acid and ether) - - - - -	(6·32 to 6·68)	6·51	(3)
Ratio of "Cellulose" to Suspended Solids - - -	(1 : 6·7 to 1 : 8·6)	1 : 7·5	(3)

The following points come out very clearly from the above analyses :—

1. The Guildford sewage is a very strong one, both as regards nitrogenous and other oxidisable matter, although not containing an exceptionally large amount of chlorine.

2. All the hourly samples were remarkably uniform in composition although two and a half years elapsed between the taking of the first and the second series, excepting that the suspended solids in the last two sets of samples come out distinctly lower than in the first three (37 parts per 100,000, as against 49 parts). This variation, however, may be partly due to the fact that in the later sets the solids were determined directly, and in the earlier sets by difference.

The first three sets of samples were noted, on analysis, as having a "sewage and beer" smell. Their suspended solids consisted largely of fibre or a network of fibrous matter, such as the skeleton of a leaf or husk; hence this sewage is obviously one which requires careful settlement or clarification before treatment. When No. 756 (in the second set) was drawn, the weekly cattle market was being held; the sewage was afterwards noted as having a soapy, tarry smell.

The one chance sample of sewage which was examined, No. 3462, drawn on 30th May, 1904, at 3 p.m., was even rather stronger than the above average samples in nitrogenous matter, and very greatly stronger as regards oxidisable matter generally and suspended solids ("Oxygen absorbed" in 4 hours = 38·98; solids by centrifuge = 577 vols.). This latter circumstance is no doubt partly accounted for by the fact that the sample of sewage contained milk refuse from a large dairy.

The sewage, therefore, is a strong and difficult one to treat.

Bacteriological results.—The results are shown in the following table, but will be considered together with the results of the examination of the septic tank and precipitation liquors later in this Report.

Description of the Sample.	B. Coli. test.	In. = Indol test. N.R. = Neutral red broth test. L.P.M. = Lactose peptone milk test. B.S. = Bile Salt glucose peptone test.	B. Enteritidis sporogenes test.	Remarks.
3014. Guildford Crude Sewage, 20/7/02.	100,000 (+indol) (+clot)	100,000 In. 100,000 N.R. 100,000 L.P.M. 100,000 B.S.	1,000 not 10,000	"Gas" test +·01 c.c. 24 hours at 20°C.
3071B. Guildford Crude Sewage, 22/7/02.	—	100,000 N R. 100,000 N.R. 100,000 B.S.	1,000 not 10,000	"Gas" test +·01 c.c. 24 hours at 20°C.
3021. Guildford Crude Sewage, 24/7/02.	—	100,000 N.R. 100,000 L.P.M. 100,000 B.S.	1,000 not 10,000	"Gas" test +·001 c.c 24 hours at 20°C.
752. Guildford Crude Sewage, 22/11/04.	100,000 (+indol) (+clot)	100,000 N.R. 100,000 B.S.	1,000 not 10,000	
756. Guildford Crude Sewage, 23/11/04.	100,000 (+indol) (+clot)	100,000 N.R. 100,000 B.S.	100 not 1,000	

THE SEPTIC TANK, DOUBLE CONTACT BED, AND PERCOLATING FILTER PROCESS.

SEPTIC TANK.

Number - - - -	One.
Size - - - -	70 feet by 50 feet.
Depth (average) - -	7 feet.
Capacity - - - -	153,000 gallons.

Construction.—The septic tank is a plain brick and cement tank, with a bottom sloping both to the centre and to the outlet valve. The sewage enters at a depth of 5 feet, and is drawn off at a depth of 2 feet. The outlet sludge valve is at the end where the sewage enters.

Flow through.—With the usual flow of 100,000 gallons in 15 hours, the flow through is once in 22·95 hours, at a rate of ·61 inch per minute.

Working.—The tank is fed with screened sewage from 6 a.m. to 9 p.m. each day. During these hours sufficient liquid passes through to fill each of the five primary contact beds twice. The liquid in the tank is stagnant between 9 p.m. and 6 a.m. During the greater part of the observations the tank was open. Towards the end, however, in consequence of the smell arising from it, it was covered over with sheets of corrugated iron.

History of the Septic Tank.—The septic tank was started on March 24th, 1900. After treating on the average about 100,000 gallons per day from this time until October 24th, 1901, it was found to require cleaning. The supernatant liquid was therefore drawn off, and the sludge was removed by ladling it into carts. The operation is said to have been attended with only slight nuisance, owing to the sludge having been thoroughly septicised. After re-starting, the tank was worked for a further period of twelve months at the same rate, and was then cleaned out again. This time, which was during our observations, an attempt was made to pump the sludge on to the adjoining field, through the stone-ware sludge main used for the same purpose with the ordinary thin precipitation sludge. The pipe, however, was not strong enough to stand the pressure caused by the pumping of such thick sludge as this proved to be, and it gave way twice under the strain. Eventually the tank was emptied by ladling the sludge into slop-carts and tipping it on to a heap close by. This operation, however, resulted in so grave a nuisance to the cluster of houses adjoining the works, that immediate and strong steps had to be taken in order to stop it. This was done by smothering the smell with sawdust, lime and soot. Three weeks elapsed before the tank could be re-started; of this, two weeks were occupied in the attempt to pump, and three days and one night in the carting.

From November 26th, 1902, when it was again brought into use, the tank worked for a further period of about five months. On beginning to give rise to a nuisance at the end of this time, it was emptied and cleaned out again,—on April 14th, 1903. On this occasion the sludge was pumped without difficulty into a large trench in the field adjoining the works, but the operation was again attended with nuisance. The tank was re-started on April 22nd, 1903, but was stopped after five weeks working in order that it might be roofed in with corrugated iron, the idea being that this might help to prevent nuisance from smell. The alteration was completed in 34 days and, after two more short stoppages, the tank took its usual quantity of 100,000 gallons per 24 hours without further need of cleaning until November 28th, 1904—a period of nineteen months. On pumping off the supernatant liquor then, the tank was found to be rather more than one third full of thick sludge. In removing this, it was found necessary to mix it with about an equal quantity of precipitation liquor, after which it was pumped into shallow trenches ploughed in a field about three quarters of a mile away from the tanks, each trench being filled in with soil as soon as the sludge had dried sufficiently. In this way the sludge was removed expeditiously and with very little nuisance, excepting in the neighbourhood of the trenches. The area of land used for the trenching was about three acres.

Amount of Sewage treated in the Septic Tank.—The amount of sewage passing through the septic tank each day is regulated by the volume required to fill the primary beds twice. Though nominally 100,000 gallons per day, it was at the commencement of our observations approximately 91,000 gallons per day, and at the end (in June, 1904) approximately 66,000.

Septic Tank Liquor (Hourly Samples).—Eight samples in all were examined chemically, including five sets of hourly samples; of the latter, Nos. 3,015, 3,018 and 3,022 were taken in sets of 72, 48 and 48 hours each, in July, 1902, and Nos 753 and 755 in sets of 24 hours each, in November, 1904 (*cf.* hourly samples of sewage). It should be noted here, however, that, whereas all the hourly sets of sewage samples were drawn according to rate of flow, the sets of septic tank liquor were drawn in equal quantities every hour, with the omission of the fractions from 10 p.m. or 8 p.m., to 5 a.m. on the following morning, from July 17th to 22nd, inclusive, owing to the stoppage of the flow of sewage into the septic tank during those hours. The effect of this stoppage would of course be to make the septic tank liquor relatively stronger than the sewage; on the other hand, the taking of the hourly samples in equal volumes would make it weaker than the true average.

The following figures were obtained :—

Parts per 100,000.		Average.	Number of Estimations.
Ammoniacal Nitrogen	(8·48 to 9·72)	9·11	(5)
Albuminoid Nitrogen	(0·73 to 1·43)	1·00	(5)
Total Organic Nitrogen	(1·80 to 2·54)	2·14	(5)
Total Nitrogen	(10·71 to 12·02)	11·25	(5)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(3·40 to 4·07)	3·61	(5)
,, ,, ,, ,, *in 4 hours*	(10·87 to 12·07)	11·42	(5)
Chlorine	(10·24 to 11·68)	11·19	(5)
Solids in suspension	(8·0 to 22·3)	15·9	(5)
Solids by centrifuge (vols.)	(67·0 to 106·0)	82·0	(5)
Ratio of solids in suspension to centrifuge solids	(1 : 3·8 to 1 : 8·4)	1 : 5·6	(5)
"Cellulose" (by alkali, acid and ether)	(3·28 to 3·32)	3·31	(3)
Ratio of "Cellulose" to solids in suspension	(1 : 5·1 to 1 : 6·8)	1 : 6·0	(3)

All the foregoing samples of septic tank liquor had a strong foul smell. Although they are not absolutely comparable with the five sets of hourly samples of sewage, they may be taken as pretty nearly so, seeing that the total nitrogen in the septic tank liquor remains the same as in the sewage; hence the following deductions are justified :—

(1) The organic nitrogen is reduced to nearly one-half in the septic tank liquor, the ammoniacal nitrogen being increased to practically the same extent that the organic nitrogen is decreased.

(2) The "oxygen absorbed" from permanganate in 4 hours is reduced to nearly one-half.

(4) The solids in suspension are reduced to one-third. This is of course a poor reduction, but at the time the first three sets of septic tank liquor were drawn, the tank was very full of sludge.

(5) The solids in suspension in the septic tank liquor are denser than those in the sewage.

(6) The "cellulose" in the septic tank liquor is exactly half what it was in the sewage, that is to say, it was not reduced in the same proportion as the total suspended solids. The microscopical examination of the two kinds of solids showed, however, less fibre in the solids of the septic tank liquor than in those of the sewage.

The actual percentage reduction figures of the hourly sets of septic tank liquor, as compared with the hourly sets of sewage, are :—

Total Nitrogen - - - - - -	No difference.
Albuminoid Nitrogen - - - - -	48 per cent. reduction.
Total Organic Nitrogen - - - - -	46 ,, ,,
"Oxygen absorbed" at once - - - -	27 ,, ,,
"Oxygen absorbed" in 4 hours - - -	48 ,, ,,
Solids in Suspension - - - - -	62 ,, ,,

Septic Tank Liquor (*Chance Samples*).—The three chance samples of septic tank liquor examined—No. 3,071, drawn December 9th, 1902, at 10 a.m.; No. 504, drawn March 24th, 1903, at 1.10 p.m.; and No. 3,346A, drawn December 31st, 1903, at 7.10 a.m.—were again fairly uniform and did not differ much in composition from the hourly samples, excepting that they contained only about half as much suspended solids. Their average figure for Total Nitrogen was 10·03, and for "Oxygen absorbed" in 4 hours 12·87.

The contact beds at Guildford, therefore, have to treat a very strong septic tank liquor.

Bacteriological Results.—The results are shown in the accompanying table. All the samples of sewage, septic tank liquor and precipitation liquor yielded positive results with ·00001 c.c., (100,000 per c.c.), when tested by the B. coli, indol, neutral red broth, lactose peptone milk and bile-salt glucose peptone tests. As regards the B. enteritidis sporogenes test, out of a total of 17 samples from the above three sources, no less than ten samples yielded a positive result with ·001 c.c. (1,000 per c.c.).

Description of the Sample.	B. Coli test.	in = Indol test. N.R. = Neutral red broth test. L.P.M. = Lactose peptone milk test. B.S. = Bile-salt glucose peptone test.	B. Enteritidis sporogenes test.	Remarks.
3015. Guildford septic tank liquor, 20/7/02.	100,000 (– indol) (– clot)	100,000 In. 100,000 N.R. 100,000 L.P.M. 100,000 B.S.	1,000 not 10,000	"Gas" test + ·1 c.c. 24 hours at 20°C.
3018. Guildford septic tank liquor, 22/7/02.	—	100,000 N.R. 100,000 L.P.M. 100,000 B.S.	100 not 1,000	"Gas" test + ·1 c.c. 24 hours at 20°C.
3022. Guildford septic tank liquor, 24/7/02.	—	100,000 N.R. 100,000 L.P.M. 100,000 B.S.	1,000 not 10,000	"Gas" test + ·01 c.c. 24 hours at 20°C.
3071. Guildford septic tank liquor, 9/12/02.	—	100,000 N.R. 100,000 L.P.M. 100,000 B.S.	100 not 1,000	"Gas" test + ·01 c.c. 24 hours at 20° C. 6,900 000 microbes per c.c. (agar at 37°C.)
753. Guildford septic tank liquor, 22/11/04.	100,000 (– indol) (– clot)	100,000 N.R. 100,000 B.S.	1,000 not 10,000	
775. Guildford septic tank liquor, 23/11/04.	100,000 (+ indol) (– clot)	100,000 N.R. 100,000 B.S.	100 not 1,000	

PRIMARY CONTACT BEDS.

Number - - - - - -	5.
Area of each - - - - -	about 400 square yards.
Total area - - - - - -	2,018 square yards.
Cubic content of each - - - -	about 330 cubic yards.
Total cubic content - - - -	1681·5 cubic yards.
Depth of Material - - - -	2 feet 6 inches.

Material. 3 beds.—Burnt ballast, broken to pass a 3 inch ring, but rejected by a ½ inch screen.
2 beds.—Clinker, broken to pass a 3 inch ring, but rejected by a ½ inch screen.

Construction.—The filter tanks are constructed of brick and cement. They are built upon made ground and are raised above the level of the surrounding land.

Distribution.—By means of grips in the ordinary material.

Working.—The beds are filled and emptied by automatic gear, put down by Messrs. Adams & Co., of York.

Except during those times when it has been necessary to clean out or to make alterations in the septic tank, the beds have received two fillings a day throughout our observations. Both fillings are made between 7 a.m. and 9 p.m. and the beds, as a rule, take an hour to fill, remain full for two hours, and rest for four hours between the first and second filling, and for about eighteen hours between the second filling of one day and the first of the next day.

The grips in the material have been turned over about once a month during our observations, and the bed surfaces have also been raked, dug over, and weeded from time to time.

Capacity.—The total cubic content of the five primary beds is 1,681·5 cubic yards. The total empty tank capacity is therefore 283,669 gallons, and the original total water capacity, on the assumption that the material occupies half the space in the tank, is 141,834 gallons. The beds were first used on August 20th, 1900, receiving septic tank liquor at the rate of two fillings per day.

We commenced our observations at Guildford in July, 1902, and on July 26th, 1902, when the beds were twenty three months old—we made our first measurements of capacity. From primary beds Nos. 2 and 4 (one a burnt ballast bed and the other a clinker bed), taken as typical, we estimate that the water capacity of all five beds at that time was about 45,600 gallons, equal to 16 per cent. of the empty tank capacity or 32 per cent. of the original water capacity. The loss of capacity had taken place chiefly in the burnt ballast beds, the ballast bed No. 2 giving a capacity of about 8,300 gallons, as against a capacity of about 10,350 gallons for the clinker bed. But it will be seen that there was a serious loss of capacity in both kind of beds. After a further run of fourteen weeks, the beds were given a complete rest of twenty-four days, and a week after restarting they were gauged again. The estimated capacity on this occasion (December 9th, 1902) was 55,500 gallons, or 19 per cent. of the original empty tank capacity. As the result of the rest, therefore, there was an estimated total gain in capacity of 9,900 gallons. The actual capacity of each bed upon which the measurement was made was:—No. 2 (burnt ballast) 9,100 gallons; No. 4 (clinker) 14,098 gallons. The gain of capacity took place, therefore, chiefly in the clinker bed. On re-starting again, however, a rapid loss of capacity occurred in the latter; on December 24th, 1902—a fortnight later—it was found to be 13,200 gallons. This therefore represented a loss of capacity in 14 days equal to 898 gallons. We ourselves made no further gaugings at Guildford; but measurements by Mr. C. Girling, the Manager of the works, on June 11th, 1904—17 months later—gave the total primary bed capacity as about 33,040 gallons, equal to 11·5 per cent. of the original empty tank capacity.

Primary Effluents.—Four chance samples of primary bed effluent, Nos. 3029, 3072, 470 and 3347B, were examined chemically, three of them being drawn at midflow and one when the bed was three-fourths empty. All of them were from the first emptying of the particular bed for the day. They were all drawn in the winter and autumn months, three of them at least in dry cold weather, and were fairly uniform in composition. Being analysed only partially, excepting in one instance, only a few figures need be given, viz.—

Parts per 100,000.		Average.	Number of Estimations.
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(1·69 to 2·46)	1·92	(4)
" " " *in 4 hours*	(5·87 to 9·51)	7·37	(4)
Solids by centrifuge (vols.)	(14·0 to 37·0)	24·0	(4)
Incubator test (by smell)		4 failed*	(4)
Smell when drawn		3 bad	(3)
Smell when analysed		3 bad	(3)

* This was taken for granted in two cases.

All these primary effluents were brownish and turbid, but without much suspended matter. Assuming that the samples represent roughly an average of the primary bed effluents, then, when compared with the *hourly* samples of (*a*) sewage and (*b*) septic tank liquor, they show the following reduction in figures :

	(*a*)	(*b*)
Calculated on the "Oxygen absorbed" *at once*	61 per cent.	47 per cent.
,, ,, ,, ,, *in 4 hours*	66 ,,	35 ,,
,, ,, ,, Centrifuge solids	93 ,,	61 ,,

(*a*) The septic tank liquor, No. 3071, and primary effluent, No. 3072, were drawn as corresponding samples, and (*b*) so were the liquor, No. 3364A, and primary effluent, No. 3347B. Comparing these, respectively, we get the following reduction figures :—

	(*a*)	(*b*)
Calculated on the Total Nitrogen	46 per cent.	—
,, ,, "Oxygen absorbed" *at once*	43 ,,	49 ,,
,, ,, ,, ,, *in 4 hours*	46 ,,	46 ,,
,, ,, Centrifuge solids	8 ,,	75 ,,

Taking all the above figures from the primary effluents together, they indicate that the primary beds remove about half the organic matter present in the septic tank liquor.

Bacteriological Results.—The results are shown in the accompanying table, but their consideration will be undertaken at a later stage of the report.

Description of the Sample.	B. coli test.	In = Indol test. N.R.—Neutral red broth test. L.P.M. = Lactose peptone milk test. B.S. = Bile-salt glucose peptone test.	B. Enteritidis sporogenes test.	Remarks.
3016. Guildford primary bed effluent, 20/7/02.	100,000 (+ indol) (+ clot)	100,000 In. 100,000 N.R. 100,000 L.P.M. 100,000 B.S.	100 not 1,000	"Gas" test + ·1 c.c. 24 hours at 20°C.
3020. Guildford primary bed effluent, 22/7/02.	100,000 (+ indol) (+ clot)	100,000 In. 100,000 N.R. 100,000 L.P.M. 100,000 B.S.	100 not 1,000	"Gas" test + ·1 c.c. 24 hours at 20°C.
3023. Guildford primary bed effluent, 24/7/02.	100,000 (+ indol) (+ clot)	100,000 In. 100,000 N.R. 100,000 L.P.M. 100,000 B.S.	100 not 1,000	"Gas" test + ·1 c.c. 24 hours at 20°C.
3029. Guildford primary bed effluent, 15/10/02.	100,000 (+ indol) (– clot)	100,000 In. 100,000 N.R. 100,000 L.P.M. 100,000 B.S.	1,000 not 10,000	"Gas" test + ·01 c.c. 24 hours at 20°C.
3072. Guildford primary bed effluent, 9/12/02.	—	100,000 N.R. 100,000 L.P.M. 100,000 B.S.	100 not 1,000	"Gas" test + ·01 c.c. 24 hours at 20° C. 2,150,000 microbes per c.c. (agar at 37°C.)
470. Guildford primary bed effluent, 15/1/03.	100,000 (+ indol) (– clot)	100,000 In. 100,000 N.R.	100 not 1,000	"Gas" test + ·1 c.c. 24 hours at 20° C. 2,700,000 microbes in 1 c.c. (agar at 37°C).

SECONDARY BEDS.

Number - - - - - - -	5.
Area of each - - - - -	about 530 square yards.
Total area - - - - -	2,741·6 square yards.
Total cubic content - - - -	2,288·2 cubic yards.
Depth of material - - - -	2 feet 6 inches.
Material - - - - -	3 beds burnt ballast, passed by a ½ inch mesh and rejected by a $\frac{1}{10}$ inch mesh.
	2 beds clinker, passed by a ½ inch mesh and rejected by a $\frac{1}{10}$ inch mesh.

Construction.—Brick and cement.

Distribution.—By means of grips in the ordinary material.

Working. – Except during a period of five weeks, in June, 1903, when they were filled once a day with precipitation liquor, and during the stoppage of the septic tank for cleaning, the secondary beds have received two fillings per day of primary bed effluent. The beds are filled and emptied by automatic gear put down by Messrs. Adams & Co., York, and are worked in exactly the same way as the primary beds. Throughout our observations the period of contact has been two hours.

Capacity.—Several attempts were made to gauge the capacity of the secondary beds, but none of them resulted satisfactorily, mainly because of the practical impossibility of filling the secondary beds except through the primary. We are consequently unable to make any accurate statement on this point. There is no doubt, however, that the loss of capacity in these beds took place at a much slower rate than in the primary beds, for in December, 1902, the effluents from some of the primary beds were only sufficient to half fill the corresponding secondary beds into which they were run.

Secondary Effluents.—Seven samples of secondary effluent were examined chemically, Nos. (3030 and 3031), 3073, 469, 3107, 502, 612 and 3348c. The first two, though analysed separately, have been averaged as one sample here, being from the same emptying of a bed, but taken at different intervals after the valve was opened. These samples were spread over spring, autumn and winter and most of them were taken in dry weather, at or about mid-flow. They gave the following figures :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - - - -	(0·70 to 1·66)	1·08	(3)
Albuminoid Nitrogen - - - - - - -	(0·37 and 0·28)		(2)
Total Organic Nitrogen - - - - - - -	(1·25 and 0·65)		(2)
Oxidized Nitrogen - - - - - - - -	(0·40 to 2·03)	1·22	(7)
"Oxygen absorbed" at 27° C. (80° F.) *at once* - -	(0·44 to 1·14)	0·78	(7)
" " " *in 4 hours* - -	(1·44 to 4·43)	2·77	(7)
Incubator test (Scudder) - - - - - - - - - -		4 passed. 2 failed.	(6)
Incubator test (by smell) - - - - - - - - - -		2 passed 2 doubtful 3 failed	(7)
Smell when drawn - - - - - - - - - - -		2 good 2 brewery* 1 bad	(5)
Smell when analysed - - - - - - - - - - -		5 good 1 brewery	(6)
Solids by centrifuge (vols.) - - - - - - -	Trace to 36·0	12·0	(7)

It is evident from the above figures that, excepting in the matter of suspended solids, of which five out of the seven samples were very free indeed, the secondary effluents at Guildford are not quite fully purified. The samples tested were

* A "brewery" odour is of course not a putrescent one.

partly opalescent, partly turbid, and two of them still retained the "brewery" smell when drawn. The "dissolved oxygen absorption" test was only applied in two instances to these effluents, but the permanganate figures are somewhat high, and the incubation results are unsatisfactory. Of course one has to bear in mind the fact that the effluents come from a strong sewage, and that they would, therefore, contain normally rather a high proportion of organic matter of a resistant nature, and consequently give figures, for permanganate absorption, etc., higher than the average. But, even allowing for this, the incompleteness of the purification is evident from the large amounts of nitrate used up on incubation by four out of the seven samples, thus:—

No.	Oxidized Nitrogen in original effluent.	Oxidized Nitrogen used up.	Smell after incubation.
3073	1·87	Probably all.	Smell like beer; suspicious.
469	1·50 approx.	All.	Putrid.
3107	2·0 approx.	All.	Putrid.
3348 C.	1·34	Nearly all.	Doubtful earthy smell.

It is pretty evident, therefore, that some of the constituents of the brewery refuse in the Guildford sewage are difficult of treatment in the contact beds, rendering the sewage harder to purify than a purely domestic sewage.

As compared with the hourly samples of (*a*) sewage and (*b*) septic tank liquor, the foregoing seven secondary effluents show the following reduction in figures:—

	(*a*)	(*b*)
Calculated on the "Oxygen absorbed" *at once*	84 per cent.	78 per cent.
,, ,, ,, ,, *in 4 hours*	87 ,, ,,	76 ,, ,,
,, ,, ,, Centrifuge solids	96 ,, ,,	85 ,, ,,

Reference may be made here to two sets of comparative samples, each comprising a septic tank liquor and a primary and secondary effluent, and the second set a tertiary effluent also. Their figures of analysis are:—

Parts per 100,000.	No. 3071 Sept. Liq.	No. 3072 Prim.	No. 3073 Sec.	No. 3346A Sept. Liq.	No. 3347B Prim.	No. 3348C Sec.	No. 3349D Ter.
Ammoniacal Nitrogen	9·03	3·41	1·66			0·88	0·75
Albuminoid Nitrogen	1·04	0·56	0·37			0·28	0·30
Total Organic Nitrogen	2·59	1·74 ap.	1·25			0·65	0·88
Nitrous Nitrogen		0·25	0·07		Trace	0·02	0·02
Nitric Nitrogen		0·30 ap.	1·80			1·32	1·52
Total Nitrogen	11·62	5·70	4·77	9·03		2·87	3·17
Oxygen absorbed from Permanganate at 27°C. (80°F.) *at once*	3·20	1·82	1·04	3·30	1·69	0·76	0·87
,, ,, ,, ,, *in 4 hours*	11·12	5·97	3·89	14·03	7·53	2·82	2·91
Disolved oxygen taken up in 24 hours at 18°C. (65°F.)							0·42
Chlorine	11·50			10·04	9·94	9·58	9·52
Incubator test (Scudder)			Passed			Passed	Passed
,, ,, (by smell)		Failed	Doubtful		Failed	Passed or Doubtful	Passed(*)
Solids in suspension							
Solids by Centrifuge (vols).	40·0	37·0	33·0	77·0	19·0	1·8	3·6

(*) Doubtful or strong earthy smell after incubation.

On a *general* review of these figures—leaving suspended solids out of account—it is seen that, as compared with the septic tank liquor, the reduction of impurity in the primary effluents amounts to about 46 per cent. and in the secondary to about 70 per cent.

Bacteriological Results.—The results are shown in the accompanying table, but it is desirable to consider them in connection with the results of the examination of the other effluents

Description of the Sample.	B. Coli Test.	In. = Indol test. N.R. = Neutral red broth test. L.P.M. = Lactose peptone milk test. B.S. = Bile-Salt glucose peptone test.	B. Enteritidis sporogenes test.	Remarks.
3017. Guildford Secondary Bed Effluent, 20/7/02.	10,000 not 100,000 (+indol) (+clot)	100,000 In. 100,000 N.R. 100,000 L.P.M. 100,000 B.S.	100 not 1,000	"Gas" test + 1 c.c. (24 hours at 20·C.)
3019. Guildford Secondary Bed Effluent, 22/7/02.	100,000 (– indol) (– clot)	100,000 In. 100,000 N.R. 100,000 L.P.M. 100,000 B.S.	100 not 1,000	"Gas" test + 1 c.c. (24 hours at 20·C.)
3024. Guildford Secondary Bed Effluent, 4/7/02.	100,000 (– indol) (+clot)	100,000 In. 100,000 N.R. 100,000 L.P.M. 100,000 B.S.	100 not 1,000	"Gas" test + ·1 c.c. (24 hours at 20·C.)
3030 Guildford Secondary Bed Effluent, 15/10/02.	100,000 (+indol) (– clot)	100,000 In. 100,000 N.R. 100,000 L.P.M. 100,000 B.S.	100 not 1,000	"Gas" test + ·01c.c. (24 hours at 20·C.)
3031. Guildford Secondary Bed Effluent, 15/10/02.	100,000 (+indol) (– clot)	100,000 In. 10,000 not 100,000 N.R. 10,000 not 100,000 L.P.M. 100,000 B.S.	100 not 1,000	"Gas" test + ·01 cc. (24 hours at 20·C.)
3073. Guildford Secondary Bed Effluent, 9/12/02.	—	100,000 N.R. 100,000 L.P.M. 100,000 B.S.	10 not 100	"Gas" test + ·01c.c. (24 hours at 20·C.) 1,010,000 microbes per c.c. (agar at 37·C.)
469. Guildford Secondary Bed Effluent, 15/1/03.	100,000 (+indol) (+clot)	100,000 In. 100,000 N.R	1,000 not 10,000	"Gas" test + ·1 c.c. (24 hours at 20·C.)
3107. Guildford Secondary Bed Effluent, 24/2/03.	100,000 (– indol) (+clot)	10,000 not 100,000 In. 100,000 N.R. 100,000 B.S.	100 not 1,000	
502. Guildford Secondary Bed Effluent, 24/3/03.	—	100 not 1,000 N.R.	1 not 10	
612. Guildford Secondary Bed Effluent, 29/9/03.	10,000 not 100,000 (+indol) (+clot)	10,000 not 100,000 N.R.	10 not 100	
3348c. Guildford Secondary Bed Effluent, 31/12/03.	100,000 (+indol) (+clot)	100,000 N.R.	100 not 1,000	

Amount of Septic Liquor treated in the Double Contact Bed Process.—The average capacity of the five primary beds between July 1902 and June 1904 was about 45,000 gallons. Two fillings per day at this mean capacity give the following figures :—

Amount treated per square yard per day on the total area of the two sets of beds - - - - - - 18·8 gallons.

Amount treated per cube yard per day on the total cubic content of the two sets of beds - - - - - 22·7 gallons.

TERTIARY BEDS OR FILTERS.

Number - - - - - - -	3.
Area - - - - - - -	No. 1 ; 139 square yards. No. 2 ; 170 ,, ,, No. 3 ; 147 ,, ,,
Total area - - - -	456 square yards.
Cubic content - - - -	No. 1 ; 96 cubic yards. No. 2 ; 129 ,, ,, No. 3 ; 190 ,, ,,
Total cubic content - - -	415 cubic yards.
Depth of material - - -	No. 1 ; 2 feet. No. 2 ; 2 feet 2 inches. No. 3 ; 3 feet 10 inches.
Material - - - -	No. 1. Burnt ballast ; everything under $\frac{1}{10}$ inch diameter. No. 2. Fine clinker and sand ; No. 3. Fine clinker and sand. } everything under $\frac{1}{10}$ inch diameter.

Distribution.—On No. 1, perforated pipes working under pressure, so as to produce a spray. On Nos. 2 and 3, wooden troughs.

Construction.—These beds are percolating filters of fine material, let into the ground. Except for the bottoms and the inspection chambers, which are of concrete, no building materials have been used in their construction.

Working.—The tertiary beds, with a small plot of grass land, take the whole of the effluent from the secondary beds, as run off from about 11 a.m. to 2 a.m. They rest from 2 a.m. to 11 a.m.

These Tertiary beds were constructed by Mr. C. G. Mason, the Borough Surveyor, during our observations, in order to further purify the secondary bed effluent before discharging it into the river. As a step in the direction of preventing the discharge of insufficiently purified effluents into rivers, they have been of great interest to us, but we have not thought it necessary accurately to gauge the amount of effluent treated upon them. As a rough estimate, we should put it down as being, at the end of our observations, about 60,000 gallons per day. At this figure, the flow per cube yard per day would be 145 gallons.

Tertiary Effluents.—Nine samples were examined chemically, viz., Nos. 3,107A1, 3,107A2, 503, 540, 611, 3,349D, 3,351, 3,357 and 675. These were drawn during spring, autumn and winter, almost all of them in dry weather, and they were for the most part taken after the beds had been restarted for about half an hour or so.

Sample No. 3,107A1 was from a comparatively new filter, and it is noticeable that it contained much more unoxidised ammonia (1·52 parts ammoniacal nitrogen) than

any of the other samples; No. 675 was a sample of last runnings and contained a mere trace of ammonia, but it is included here. The following figures were obtained on analysis :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - - - -	(0·04 to 1·52)	0.51	(8)
Albuminoid Nitrogen - - - - - - -	(0·03 to 0·30)	0·18	(8)
Total Organic Nitrogen - - - - - - -	(0·03 to 0·94?)	0·58	(4)
Oxidized Nitrogen - - - - - - - -	(1·54 to 2·80)	2·17	(9)
Total Nitrogen - - - - - - - - -	(1·93 to 3·59)	2·99	(5)
"Oxygen absorbed" at 27° C. (80° F.) *at once* - - -	(0·03 to 0·87)	0·43	(9)
,, ,, ,, ,, *in 4 hours* - -	(0·63 to 2·91)	1·76	(9)
Dissolved Oxygen taken up in 24 hours at about 18° C. -	0·42 to 1·04)	0·72*	(7)
Incubator test (Scudder) - - - - - - - - - -		9 passed	(9)
Incubator test (by smell) - - - - - - - - - -		9 passed	(9)
Smell when drawn - - - - - - - - - - -		†7 good	(7)
Smell when analysed - - - - - - - - - - -		9 good	(9)
Chlorine - - - - - - - - - - -	(7·72 to 10·40)	9·12	(4)
Solids by Centrifuge (vols.) - - - -	(Minute trace to 19·0)	3·4	(9)
Parts per 1,000, by volume.			
Oxygen in Solution when analysed - - - -	(0·0 to 5·25)	2·5	(9)

* No. 675, an excellent effluent, gave the very high figure of 1·64 for dissolved oxygen absorption; this was, however, totally out of keeping with all the other figures of analysis and it has been rejected as being in all probability due to some error.

† Two of these still retained a very faint brewery smell when they came to be analysed.

Coming from a strong sewage, difficult to treat, like that at Guildford, these effluents were in most respects of good quality. Excepting in the case of No. 3,351, when frost on the surface of the bed had evidently affected its working to some extent, they contained only traces or little more than traces of suspended solids, were inoffensive as regards smell, and withstood incubation. By far the greater part of the nitrogen that they contained was in the form of nitrate, and the figures of analysis generally were good.

It will, however, be observed that these effluents, though good in other respects, were not completely oxidized, as is shown by the amount of dissolved oxygen they took up in 24 hours (average 0·72 part per 100,000); this is a further corroboration of the difficulty of thoroughly oxidizing a brewery sewage.

As compared with the hourly sets of sewage and septic tank liquor, respectively, these tertiary effluents show the following percentage reduction in figures :—

	(*a*) Sewage.	(*b*) Septic Tank Liquor.
Calculated on the Albuminoid Nitrogen - - - - - - -	91 per cent.	82 per cent.
,, ,, Oxygen absorbed *at once* - - - - - -	91 ,,	88 ,,
,, ,, ,, *in 4 hours* - - - - - -	92 ,,	85 ,,
,, Centrifuge Solids - - - - - - - -	99 ,,	96 ,,

Too few estimations of total nitrogen were made in these effluents to allow of a definite general deduction, but, speaking roughly, only about one quarter of the nitrogen of the septic tank liquor remains in the tertiary effluent.

Bacteriological Results.—The results are shown in the accompanying table.

Description of the Sample.	B. Coli test.	In = Indol test. N.R. = Neutral red broth test. L.P.M. = Lactose peptone milk test. B.S. = Bile-salt glucose peptone test.	B. Enteritidis Sporogenes test.	Remarks.
3107 A1. Guildford tertiary bed effluent, 24/2/03.	1000,000 (– indol) (– clot)	10,000 not 100,0000 In. 100,000 N.R. 10,000 not 100,000 B.S	10 not 100	
3107 A2. Guidford tertiary bed effluent, 24/2/03.	—	100,000 N.R. 100,000 B.S.	10 not 100	
503. Guildford tertiary bed effluent, 24/3/03	—	100,000 N.R.	1 not 10	
540. Guildford tertiary bed effluent, 26/5/03	—	10,000 not 100,000 N.R.	100 not 1,000	
611. Guildford tertiary bed effluent, 29/9/03	—	100,000 N.R.	1 not 10	
3349B. Guildford tertiary bed effluent, 31/12/03	100,000 (+indol) (+clot)	100,000 N.R.	10 not 100	
3351. Guildford tertiary bed effluent, 31/12/03	100,000 (+indol) (+clot)	100,000 N.R.	10 not 100	
675. Guildford tertiary bed effluent, 12/4/04	100 not 1,000 (+indol) (+clot)	100 not 1,000 N.R.	1 not 10	

Considering the effluents from the three sets of beds together, the following notes are of interest:—

The effluents from the primary, secondary, and tertiary beds yielded, almost without exception, positive results with the B. coli, indol, neutral red broth, lactose peptone milk, and bile-salt glucose peptone tests with ·00,001 c.c. (100,000 per c.c.), and more than half the samples positive results with the B. enteritidis sporogenes test with ·01 c.c. (100 per c.c.). Guildford sewage is a very strong one, but even allowing for this circumstance the effluents were unsatisfactory, bacteriologically. Nevertheless, one sample of last runnings of a tertiary effluent (675) yielded good results, containing less than 1,000 B. coli per c.c. and yielding a negative result with the B. enteritidis sporogenes test with $\frac{1}{10}$ c.c.

THE PRECIPITATION, STREAMING FILTER, AND LAND PROCESS.

PRECIPITATION TANKS.

Number	2 (originally 3).
Size of each	71 feet 9 inches by 50 feet.
Depth	5 feet 8 inches (average).
Capacity of each	132,000 gallons.
Total capacity	264,000 gallons.
Construction	Concrete bottom, with cement and brick walls.

Precipitant.—Alumino-ferric. Amount.—About 8 grains per gallon. Method of adding.—Blocks of the precipitant are placed in the sewage channel.

Flow through.—With a flow of 300,000 gallons per day, the flow through the precipitation tanks would be about once in 10·5 hours, at a rate of ·95 inch per minute.

Working.—Only one tank at a time is used at Guildford in the precipitation process. It is worked for two days and then sludged. In ordinary weather, each tank is sludged three times a week, the tank in use at the end of the week running for three days instead of two.

Sludging.—Most of the sludge remaining in the tank, after the supernatant liquid has been removed, is liquid enough to flow to the pump, but the last part has to be pushed to the outlet valve with squeegees. It is pumped in its semi-liquid state on to some adjoining land and ploughed in, and there is no doubt that the land, which is of a sandy nature, has been improved thereby. A considerable smell arises, however, from this precipitation sludge, as it dries, before it can be ploughed in.

Amount of sewage treated.—The total dry weather flow of sewage is 400,000 gallons per day. About one quarter of this is treated in the septic tank and by the bacteria beds, and the dry weather flow through the precipitation tanks and on to the land is therefore about 300,000 gallons per day. On the average, however, considerably more than this is treated by the latter process, as the flow through the septic tank is an almost constant one, and all the additional flow in times of storm goes through the precipitation tanks.

On the dry weather estimate of 300,000 gallons per day, the 12 acres of land treat the liquor from the precipitation tanks and streaming filters at the average rate of 25,000 gallons per acre per day,—a large volume.

Precipitation Liquor.—Six samples in all were examined chemically, viz., two sets of hourly samples, extending over 24 hours each, and four chance ones.

The two sets of hourly samples, Nos. 751 and 754, were taken according to rate of flow of sewage, in November, 1904; about 0·08 inch of rain fell during the first night of sampling. They were very similar to one another in composition, and may therefore be safely taken as a good average. They gave the figures :—

	Parts per 100,000.	Average.
Ammoniacal Nitrogen	(7·41 and 7·46)	7·34
Albuminoid Nitrogen	(1·35 and 1·31)	1·33
Total Organic Nitrogen	(3·87)*	3·87
Total Nitrogen	(11·13)*	11·13
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(3·25 and 2·80)	3·03
"Oxygen absorbed" ,, *in 4 hours*	(21·66 and 18·41)	20·04
Chlorine	(11·90 and 11·00)	11·45
Solids in suspension	(17·00 and 12·20)	14·60
Solids by Centrifuge (vols.)	(57·0 and 52·0)	55·0
Ratio of solids in suspension to Centrifuge solids	(1 to 3·4 and 1 : 4·3)	1 : 3·9

* The first estimation of Total Nitrogen, and therefore of Total Organic Nitrogen, was unfortunately lost.

If these figures be compared with those given by the average samples of septic tank liquor it will be seen that, while the total nitrogen is practically the same in both cases, the organic nitrogen and "oxygen absorbed" are much higher in the precipitation liquor. We have, however, no comparative data here as regards the question whether one of these liquids would be more easy to treat on a biological filter than the other. With reference to the rather large quantity of suspended solids left in the precipitation liquor, it should be borne in mind that the precipitation tank capacity at Guildford is now less than was originally designed (one of the tanks having been converted into a septic tank), and that the flow through the tanks is rapid.

As compared with the five hourly sets of sewage samples, the following reduction is shown :—

Calculated on Albuminoid Nitrogen	31	per cent.
"Oxygen absorbed" *at once*	39	"
" " *in 4 hours*	9	"
" " Suspended Solids	75	"

The four chance samples of Precipitation Liquor, Nos. 621, 3350, 674 and 3541, of which the first three were drawn in dry weather and the last one in wet, naturally varied considerably in composition, and were upon the whole only about two-thirds as strong at the hourly samples; their suspended solids were evidently very light and flocculent. They gave the figures :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(8·15 and 5·44)		(2)
Albuminoid Nitrogen	(1·01 and 0·81)		(2)
Total Organic Nitrogen	(2·79 and 1·45)		(2)
Total Nitrogen	(6·89 to 10·94)	7·77	(3)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(1·87 to 3·21)	2·43	(4)
" " " " *in 4 hours*	(9·06 to 17·50)	13·07	(4)
Chlorine	(7·16 to 10·30)	8·47	(3)
Solids in suspension	(4·30 to 11·90)	9·00	(3)
Solids by Centrifuge (vols.)	(22·0 to 95·0)	54·0	(3)
Ratio of solids in suspension to Centrifuge solids	(1 : 10·7 and 1 : 8·8)		(2)

Bacteriological Results.—The results are shown in the following table. They have already been considered in connexion with the results of the examination of the sewage and septic tank liquor.

Description of the Sample.	B. coli test.	In. = Indol test. N.R. = Neutral red broth test. L.P.M. = Lactose peptone milk test. B.S. = Bile-salt glucose peptone test.	B. Enteritidis Sporogenes test.	Remarks.
621. Guildford precipitation liquor, 8/10/03.	100,000 (+ indol) (+ clot)	100,000 N.R.	100 not 1,000	
3350. Guildford precipitation liquor, 31/12/03.	100,000 (– indol) (+ clot)	100,000 N.R.	10 not 100	
674. Guildford precipitation liquor, 12/4/04.	100,000 (+ indol) (+ clot)	100,000 N.R.	1,000 not 10,000	
3541. Guildford precipitation liquor, 17/8/04.	100,000 (+ indol) (+ clot)	100,000 N.R. 100,000 B.S.	1,000 not 10,000	
751. Guildford precipitation liquor, 22/4/04.	100,000 (– indol) (+ clot)	100,000 N.R. 100,000 B.S.	1,000 not 10,000	
754. Guildford precipitation liquor, 23/11/04.	100,000 (+ indol) (+ clot)	100,000 N.R. 100,000 B.S.	100 not 1,000	

STREAMING FILTERS.

Number - - - -	6.
Size of each - - - -	61·5 feet by 28·66 feet
Depth - -	3 feet.
Area of each - - - -	195·8 square yards.
Total area - - - - -	1175·0 square yards.
Cubic content of each - - -	195·8 cubic yards.
Total cubic content - - -	1175·0 cubic yards.

Material.—5 beds: Coke and gravel (medium size). 1 bed: Sand and polarite, with a little clinker (fine material).

Working.—These filters are used, irregularly, between 6 a.m. and 5 p.m. each day, by streaming precipitation liquor through them, with a single trough distribution. They rest all night.

As a rule, it is impossible to get all the precipitation liquor through these filters, and a considerable portion of it usually flows over the filter surface direct to the land. The precipitation liquor which passes through the filters no doubt has some of its suspended matter removed, and, in the early part of each day's work, is probably oxidised; but, as observations upon those filters did not come within the scope of our work at Guildford, we drew no samples.

LAND.

Total area.—During our observations, 12 acres.

Divisions.—12 plots of about 1 acre each.

Nature of soil and subsoil.—Sand and gravel, of which the gravel preponderates.

Depth of drains.—6 feet.

Working.—The plots are worked in rotation, each plot being fed with precipitation liquor and streaming filter effluent for as long as it will take water. This, in dry weather, is usually about 3 days. The whole flow of precipitation tank liquor and streaming filter effluent goes on to the plot in use.

Cropping.—The plots are not cropped, excepting that rye grass is occasionally grown on some of them.

Amount treated by the land.—The dry weather flow of sewage treated in the precipitation tanks and upon the streaming filters and land is about 300,000 gallons per day. On this basis, therefore, the amount treated per acre per day is 25,000 gallons, but, since the whole flow goes on to the plot in use, the very high actual rate of 300,000 gallons per acre per day is attained.

Effluents from Land.—Only three land effluents were examined chemically, viz., Nos. 620, 3542 (a mixed land and tertiary effluent), and 738. The first of these, No. 620, was very yellow and turbid from finely-divided oxide of iron, which deposited on standing for some time; but, apart from this, it was an effluent of fair quality. It is worthy of note that no oxidized nitrogen (or practically none) was present in it, and yet it withstood incubation.

No. 3542, a mixed land and tertiary effluent, was of poor quality, contained 6·3 parts of suspended solids, and failed to withstand incubati on.

No. 738, drawn after heavy rain, was an effluent of vry high class.

These two last-mentioned effluents were partially examined, both before and after filtration through paper, and the following figures are therefore of interest:—

Parts per 100,000.	No. 3542.		No. 738.	
	Original.	Filtered.	Original.	Filtered.
"Oxygen absorbed" at 27° C. *at once*	1·46	1·19	0·19	0·11
" " " *in 4 hours*	3·73	2·55	0·56	0·54
Dissolved Oxygen taken up at about 18° C. in 24 hours	1·28	0·32	0·07	0·02
Incubator test (by smell)	Failed	Passed	Passed	Passed
Solids in Suspension	6·3			
Solids by Centrifuge (vols.)	52·0		*20 (?)	

* These solids settled badly in the Centrifuge tube.

In the first of these samples the suspended solids were evidently the main impurity; in the second, the little suspended solid present was innocuous.

With so few samples, it would be unwise to attempt any general deductions with regard to the land effluents.

Bacteriological Results.—The results are shown in the accompanying table. Excluding sample 3542, a mixed land and tertiary effluent, the two land effluents (620 and 738) yielded very good results. Both samples yielded a negative result with 1 c.c, with the B. enteritidis sporogenes test. Sample 620 yielded a negative result with 1/100 c.c. (neutral red broth test); sample 738 contained less than 1,000 B. coli per c.c., and the neutral red broth and bile-salt glucose peptone tests yielded negative results with 1/10,000 and 1/1,000 c.c. respectively. On the other hand, sample 3542 yielded positive results with ·00001 c.c. (100,000 per c.c.) with the B. coli, neutral red broth and bile-salt glucose peptone tests. The B. enteritidis sporogenes test yielded positive results with ·01 c.c. (100 per c.c.). The bacteriological results are, therefore, in close harmony with the chemical results.

Description of the Sample.	B. coli test.	In = Indol test. N.R. = Neutral red broth test. L.P.M. = Lactose peptone milk test. B.S. = Bile salt glucose peptone test.	B. Enteritidis sporogenes test.	Remarks.
620. Guildford land effluent 8/10/03	—	Negative 1/100 c.c. N.R.	Negative 1 c.c.	
738. Guildford land effluent 17/10/04	100 not 1,000 (+ indol) (+ clot)	1,000 not 10,000 N.R. 100 not 1,000 B.S.	Negative 1 c.c.	
3542. Guildford mixed land and tertiary effluent 17/8/04	100,000 (– indol) (– clot)	100,000 N.R. 100,000 B.S.	100 not 1,000	

Effect of Temperature upon the Tanks and Filters.

Measurements of temperature were taken on the occasion of each visit to the works, and also every few hours throughout a whole week in July, 1902. None of the ordinary fluctuations in temperature, either of the sewage or the atmosphere, during 1903-4, had any marked effect upon the working of the tanks or contact beds. During some

frosty weather in December, 1903, however, the surface of the material on the tertiary beds became loosened and disturbed, owing to the freezing of the absorbed water when the beds were at rest; to effect good distribution, the material must of course remain closely bound together. A sample of effluent from No. 1 tertiary bed, taken at this time, showed that the bed was not working so well as usual. On this occasion, also, the secondary effluent feeding the bed fell from 8° C. to 5·5° C. in passing through the tertiary bed, thus losing 2·5° C. in the process.

SUMMARY.

The sewage is very strong, both as regards nitrogenous and other oxidisable matter; it contains much brewery refuse.

As regards the comparative preliminary treatment of the Guildford sewage by septic tank on the one hand and by precipitation on the other, our observations have led us to the following conclusions:—

With about half the rate of flow of the precipitation liquor, the septic tank liquor contained on the average 16 parts per 100,000 of suspended solids,* as against 15 parts in the precipitation liquor. On the other hand, the septic tank treatment had the unusual effect of reducing the organic nitrogen and also the oxidisable matter, as measured by the "oxygen absorbed in 4 hours," to a much greater extent than the precipitation process. We should expect, therefore, although comparative experiments are wanting, that the septic tank liquor at Guildford would be more easy to purify than the imperfectly clarified precipitation liquor produced there.

We have made no quantitative observations as to the amount of digestion which goes on in the Guildford septic tank.

The working of the septic tank undoubtedly caused a certain amount of nuisance, for which the brewery refuse must have been to some extent responsible, and also the stagnation of the liquor in the tank at night; while its emptying was productive of great nuisance on two occasions out of three. On the third occasion the method of emptying the tank was altered, with the result that the nuisance was greatly lessened.

The volume of septic tank liquor treated per cube yard of primary bed, per day, was 54 gallons. By this treatment the organic matter of the tank liquor was reduced by about one half, but this purification was accompanied by a very rapid and pronounced loss of capacity in the beds themselves. A considerable part of this loss in the beds of burnt ballast was caused by the breaking down of the bed material; the diminution in capacity was less marked in the case of the clinker beds, though in these it was serious also. The loss of capacity was no doubt due in very large degree to the quantity and quality of the suspended solids present in the septic tank liquor; but we should like to say—as an expression of opinion—that we think the shallowness of the primary beds had also something to do with it, these beds being only 2 feet 6 inches deep. When a bed clogs, it does so mainly from the top downwards, and the top portion necessarily bears a larger ratio to the total cubic content in a shallow bed than in a deep one.

The volume of primary effluent treated on the secondary beds was 39 gallons per cube yard per day, the reduction in the carbonaceous organic matter of the septic tank liquor by the primary and secondary beds together being about 80 per cent.† This purification, however, was not sufficient to produce a uniformly non-putrescible effluent.

We were unable to estimate the loss of capacity in the secondary beds, but we are satisfied that it was not serious.

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* This figure (16) applies to the particular time when the hourly samples of septic tank liquor were drawn the tank then having run for a period of nineteen months. It should, however, be borne in mind that, in order to get a true average of the suspended solids in a septic tank liquor, samples ought to be taken over a long period of time.

† This figure is from the comparison of the "Oxygen absorbed" figures given by the hourly samples of septic tank liquor and the chance samples of secondary effluent.

The automatic gear used for filling both the primary and the secondary beds at Guildford has certain disadvantages. It works satisfactorily for a considerable time, but is apt eventually to get out of order, in which case the particular bed is thrown out of cycle. Again, in emptying, after a bed has been sufficiently emptied for the action of the syphon to be "broken," the drainings from the upper portion of the bed gradually accumulate at the bottom—in other words, the bed is not thoroughly run off.

We have estimated roughly the volume of secondary effluent treated on the three tertiary (percolating) beds to be about 145 gallons per cube yard per day. No. 1 bed is of extremely fine material throughout, being composed of the small riddlings and dust from the burnt ballast used in some of the secondary beds. The liquid is distributed on it by means of perforated pipes laid on the surface of the bed, which work under pressure, so as to produce a spray, and this distribution is fairly good. Nos. 2 and 3 are of medium-sized clinker throughout, excepting that No. 3 has a layer of sand on the top, two inches deep; the distribution on these two beds is by means of wooden troughs and is not good. Bed No. 1 ponds up considerably with liquid after it has been used for some time; No. 2 does not pond up; but No. 3 does so to some extent, though in a lesser degree than No. 1.

The varying rate at which liquid flows on to these beds at different stages of the emptying of the secondary beds makes their working irregular. To draw a comparison between them is therefore difficult, but, speaking generally, Bed No. 1 gave the best results.

The tertiary effluents were on the whole of good quality, chemically, though not quite so good as we should have expected at first sight. Bacteriologically they were unsatisfactory, with the exception of No. 675 (a sample of last runnings from No. 1 Bed). The faulty distribution of secondary effluent and the irregular working of the tertiary beds were no doubt to a large extent the reasons why the tertiary effluent did not reach a uniformly higher standard of purity.

Apart from the nuisance formerly caused by the septic tank, which has now been materially lessened, there is always considerable smell from the screening of the sewage as it enters the works.

We are indebted to Mr. C. G. Mason, the Borough Surveyor, and to Mr. C. Girling, the Manager of the sewage works, for much help in connection with our work at Guildford.

HALTON SEWAGE WORKS.

(Hunslet Rural District Council).

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1. Situation of works: about half a mile from Halton and 4 miles from the centre of Leeds.

2. Method of Treatment - - - - - -	Continuous flow settlement, double contact filtration through rather rough material, and land treatment.
3. Population draining to works during observations - - - - - - - - -	About 2,000.
4. Water supply in gallons per head and whence obtained - - - - - - - -	11 gallons; from the Leeds water supply—a soft moorland water.
5. Number of W.C.'s connected - - - -	117 (June, 1902).
6. Sewerage system - - - - - -	Combined.
7. Average dry weather flow of sewage in gallons per 24 hours - - - - - - - -	35,000
8. Gallons of sewage per head per day - -	17·5
9. Character of the sewage - - - - -	Mainly a slop water sewage.
10. Period of observations - - - - -	May, 1902 to August, 1903.
11. Age of beds - - - - - - -	Primary beds, 3 years; Secondary beds, 1 year.
12. Amount of storm water treated on filters - -	About twice the dry-weather flow.
13. Total capacity of tanks in gallons - - -	22,500
14. Total area of filters in yards super - - -	533
15. Total cubic content of filters in yards cube -	644
16. Nature of filtering medium - - - -	Primary beds — stone, coke, clinker, and pea gravel. Secondary beds—coke.
17. Gallons of settled sewage treated per yard super per 24 hours (all filters included) - - -	128
18. Gallons of settled sewage treated per yard cube per 24 hours - - - - - - -	106
19. The final effluent is discharged into - -	The Whitebeck a tributary of the River Aire, adjoining it about $1\frac{1}{2}$ miles below Knostrop.

Diagram K.

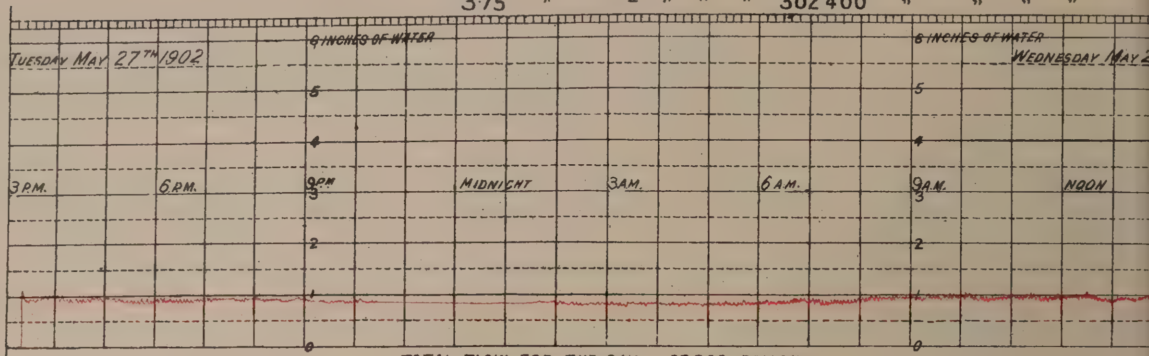
DIAGRAMS SHOWING FLOW OF SEWAGE AT HALTON

AS FALLING OVER A WEIR 12" WIDE.

Note:- Over a Weir 12" wide

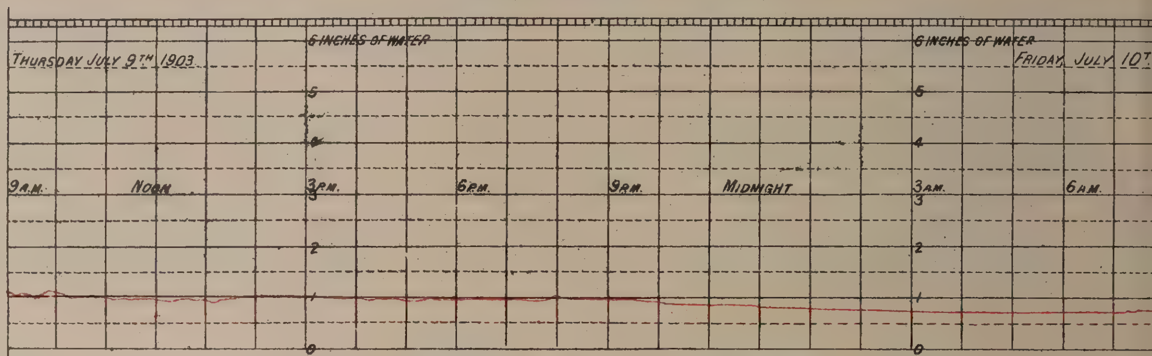
0·75	inch	= a rate of	27,360	gallons per 24 hours.
1·0	"	= " " "	41,760	" " " "
1·5	inches	= " " "	76,464	" " " "
2·0	"	= " " "	118,080	" " " "
3·0	"	= " " "	216,000	" " " "
3·75	"	= " " "	302 400	" " " "

DRY DAY.
RAINFALL NIL.



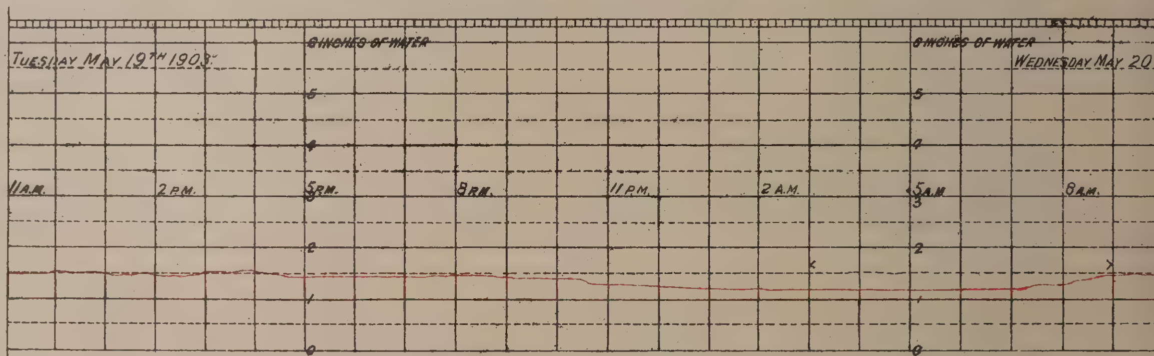
TOTAL FLOW FOR THE DAY = 37,800 GALLONS.

DRY DAY.
RAINFALL NIL.



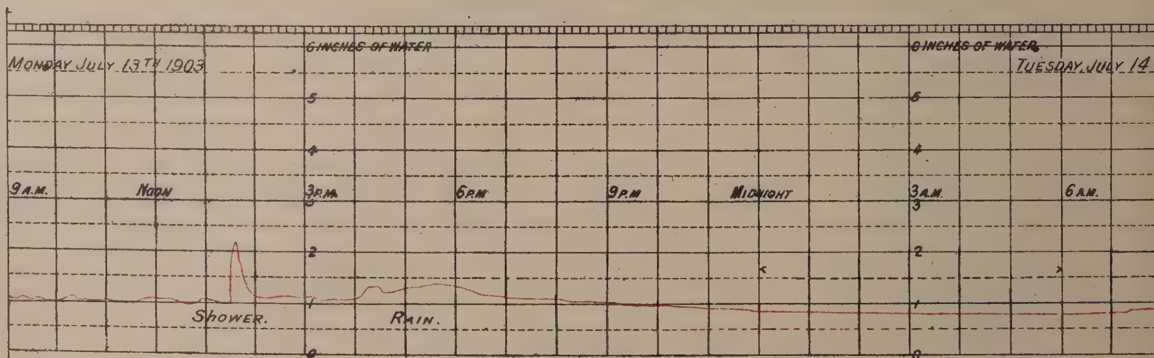
TOTAL FLOW FOR THE DAY = 35,050 GALLONS.

DRY DAY.
RAINFALL NIL.
(DRY FOR SOME DAYS BUT WET PREVIOUSLY)



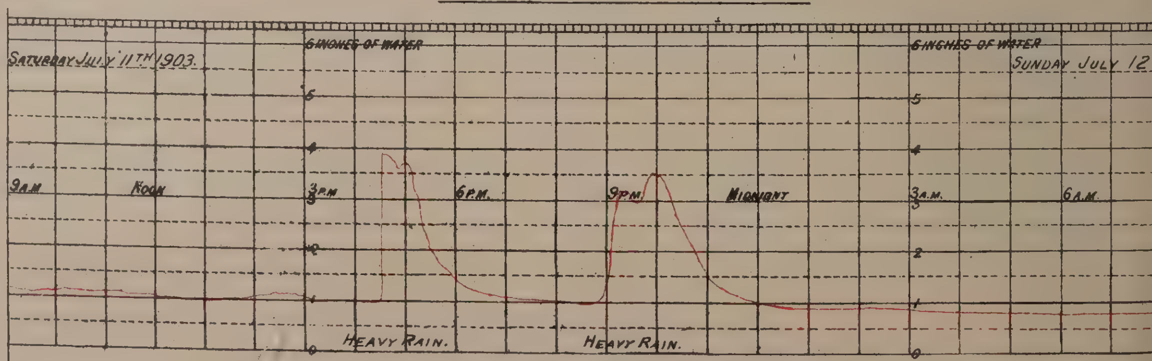
TOTAL FLOW FOR THE DAY = 66.450 GALLONS

SHOWERS ON DRY GROUND.



TOTAL FLOW FOR THE DAY = 39.300 GALLONS

THUNDER SHOWERS ON DRY GROUND.



TOTAL FLOW FOR THE DAY = 58,980 GALLONS.

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FLOW OF SEWAGE.

Our gauging records show that a considerable quantity of subsoil water gets into the sewers (probably for the most part into the Halton Sewer) when the drainage area is wet, and that it has the effect of making the sewage flow a very uniform one during the wet months of the year In summer the variations in the flow of sewage are much more marked.

It is impossible to be precise in any statement as to the amount of storm water treated upon the filters, for it varies very much, according to the season of the year. In summer, when the periods of storm flow are short, the great bulk of storm water passes through the beds; while in winter we estimate that an amount equal to about 3 dilutions of the normal 24 hours dry weather flow is filtered through them, and that any excess over this goes to the land without passing through the tanks or beds.

We have measured a flow of sewage reaching 10 dilutions of the dry weather flow for a short time, all of which was treated upon the beds, but it is to be specially noted that the total flow for the 24 hours when this took place was not more than twice the dry weather flow.

From May 29th, 1902, to March 4th, 1903, in an exceptionally wet year, the combined filters treated an average of nearly twice the dry weather flow of 35,000 gallons every day, and from March 4th, to July 9th, 1903, during which period the weather was even wetter, an average of nearly three times the dry weather flow was filtered daily.

We measured the flow by means of a Glenfield Kennedy automatic recorder, registering the height of water falling over an accurately constructed brass weir at four different times during 15 months:—

1. The first period of measurement was from May 22nd to 29th, 1902, inclusive.
   A typical dry weather flow was about 38,000 gallons per 24 hours.
   The greatest day's flow (wet day) was 97,000 gallons per 24 hours.
   The lowest day's flow (dry day) was 37,780 gallons per 24 hours.

2. On March 3rd, 1903, a wet day, the recorder gave 74,700 gallons as the flow in 24 hours.

3. The third measurement was made on May 19th, 1903, also in wet weather, when the flow was 66,460 gallons per 24 hours.

4. In July, 1903, the flow was measured over seven days (7th–13th, inclusive).

   A typical dry day's flow was about 34,000 gallons per 24 hours.
   The greatest day's flow was about 66,400 gallons per 24 hours.
   The lowest day's flow was about 34,000 gallons per 24 hours.

From these and other figures we have arrived at the following estimates, which we consider fairly representative:—

Year 1902–3.	Gallons per 24 hours.
Dry weather flow to works	35,000
Wet weather flow to works	100,000
Highest rate of flow in dry weather	50,400
Highest rate of flow in wet weather	300,000
Lowest rate of flow in dry weather	24,000

On Diagram K are given some illustrations of the sewage flow at Halton.

Crude Sewage.—The following samples were examined chemically:—

Three sets of hourly samples, Nos. 3182, 3184 and 3190 (these may be looked upon as dry weather samples); one sample of weak night sewage, No. 3186; and two ordinary chance samples, Nos. 3092 and 3110.

The hourly samples drawn over three days (not consecutive)—Tues.-Wed., Wed.-Thurs., and Mon.-Tues. in July 1903, gave the following figures :—

	Parts per 100,000.	Average.	Number of Estimations	Weak Night Sewage, No. 3186, drawn July 9th, 1903, 5 a.m.
Ammoniacal Nitrogen - - - - - - -	(4·33 to 5·10)	4·74	(3)	0·69
Albuminoid Nitrogen - - - - - - -	(0·76 to 1·00)	0·90	(3)	0·15
Total Organic Nitrogen - - - - - -	(1·20 and 0·89)	—	(2)	0·38
Total Nitrogen - - - - - - - -	(5·53 to 5·87)	5·69	(3)	1·07
"Oxygen absorbed" at 27° C. (80° F.) *at once* -	(2·40 to 2·74)	2·53	(3)	0·31
,, ,, *in 4 hours* -	(9·14 to 15·82)	11·83	(3)	1·41
Chlorine - - - - - - - - - -	(7·38 to 8·96)	8·05	(3)	3·56
Solids in Suspension - - - - - - -	(14·4 to 22·5)	17·70	(3)	1·80
Solids by Centrifuge (volumes) - - - -	(95·0 to 126·0)	113·3	(3)	19·0
Ratio of Solids in Suspension to Centrifuge Solids -	{1 to 6·6, 7·3 and 5·6}	1 : 6·4	(3)	—

It will be seen from the above figures that the sewage is of about medium strength, but with a small proportion of suspended solids. The samples for the two first days, Nos. 3182 and 3184, had almost the same composition; the sample for the third day, No. 3190, drawn during showery weather, but with the ground dry, was somewhat stronger, no doubt because of the sewers being washed out to some extent.

Of the two *chance samples*, No. 3092, drawn Monday, January 19th, 1903, at 4 p.m. after dry weather, was much stronger, and No. 3110, drawn Wednesday, March 4th 1903, at 10.45 a.m., after rain, was weaker, than the hourly samples.

No. 3186, the sample of *weak night sewage*, was very dilute.

Chemically speaking, there was nothing abnormal about the sewage, excepting that it was evidently of a soapy character.

Bacteriological Notes.—See under Settled Sewage in a later part of the Report.

SETTLING TANKS.

There are two settling tanks, each 25 feet by 12 feet, and having a water depth of 6 feet. They were constructed in 1896 of cement concrete and brickwork.

The working capacity of each tank is 11,250 gallons and the total tank capacity therefore 22,500 gallons.

The tanks are used in series.

"*Flow through.*"—In dry weather, with a sewage flow of 35,000 gallons per 24 hours, the flow through would be once in 15½ hours, at a rate of 0·66 inch per minute. In wet weather, with a sewage flow of 300,000 gallons per 24 hours, the flow through would be once in 1·8 hours.

Cleaning.—During our observations each tank has been cleaned out every seven weeks. The cleaning was done as follows:—Directly the accumulated sludge at the bottom of a tank began to ferment at all strongly, the whole of the sewage was passed through

the second tank, and when the supernatant liquid in the first tank had been drained off to the land, the sludge was allowed to flow (mixed with some sewage, if necessary), through the sludge valve into one of two small sludge lagoons at the side of the tanks. The lagoons have clinker bottoms and are under-drained. The operation took about four hours and there was a certain degree of smell during this time, but once in the lagoon there appeared to be little or no smell from the sludge.

At a rough estimate, 75 cubic yards of fairly thick sludge were dealt with in this way every seven weeks (or about 600 cubic yards a year), throughout the period of our observations.

There is no permanent accumulation of sludge upon the works, as it is readily taken by farmers when it becomes dry enough.

Settled Sewage.—The following samples were examined chemically :—

Three sets of hourly (dry weather) samples, Nos. 3183, 3185 and 3191, drawn at the same times and under the same conditions as the hourly sets of crude sewage; one ordinary chance sample, No. 3112A, drawn in March, 1903, after wet weather; and one experimental chance sample, No. 3091A, drawn in January, 1903, during a thaw, with melting snow.

The *hourly samples* gave the following figures :—

	Parts per 100,000.	Average.	Number of Estimations
Ammoniacal Nitrogen	(4·61 to 4·84)	4·72	(3)
Albuminoid Nitrogen	(0·59 to 0·83)	0·69	(3)
Total Organic Nitrogen	(0·88 to 1·27)	1·11	(3)
Total Nitrogen	(5·49 to 6·11)	5·84	(3)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(2·04 to 2·61)	2·31	(3)
" " " *in 4 hours*	(7·49 to 8·79)	8·33	(3)
Chlorine	(7·40 to 10·00)	8·44	(3)
Solids in Suspension	(5·6 to 16·9)	10·7	(3)
Solids by Centrifuge (volumes)	(44·0 to 76·0)	57·0	(3)
Ratio of Solids in Suspension to Centrifuge Solids	{1:4·5, 5·4, and 7·9}	1·5·9	(3)

These hourly samples of settled sewage were of very equal composition, excepting that No. 3183 contained an undue proportion of suspended solids, owing to the tank not having been cleaned out for some time. The settlement, on the whole, was not very good, for the suspended solids were only reduced from 17·7 parts to 10·7 parts (a reduction of 40 per cent); the reduction in the figures for "oxygen absorbed" in 4 hours was 30 per cent.

The chance sample, No. 3112A, drawn at 1 p.m. was very weak, with 7·7 parts of suspended solids. The other chance sample, No. 3091A, which was a mixture of settled sewage and primary effluent, was likewise weak, with about 4 parts of suspended solids.*

Bacteriological Notes.—As only a few samples were examined, and as the results of the examination of the crude sewage and settled sewage were fairly similar, it is desirable to give all the results in one table :—

* The actual figure for suspended solids was 3·84 parts per 100,000, but this filtrate deposited an additional quantity of 0·92 part after standing for seven days.

Results of the Bacteriological Examination of Samples of Crude Sewage and of Settled Sewage obtained from Halton.

Description of the sample.	Number of B. coli (or gas-forming coli-like microbes.)	B.S.—Bile-salt glucose peptone test. N.R.—Neutral red broth test. In.—Indol test. L.P.M.—Lactose peptone milk test.	B. enteritidis sporogenes test.	Remarks.
3092 Crude sewage- 19/1/03	—	100,000 N.R.	100 to 1,000	3092. Total No. of microbes, 68 million (gelatine at 20°C); $5\frac{1}{2}$ million (agar at 37°C), "Gas" test + ·01 c.c. (24 hours); + ·0001 c.c. (48 hours); + .00001 c.c. (72 hours).
3110 Crude sewage- 4/3/03	100,000 (— indol) (+ clot)	100,000 N.R. 100,000 B.S. 100,000 In.	100 not 1,000	
3186 Crude sewage- 9/7/03	—	10,000 not 100,000 N.R.	10 not 100	
3190 Crude sewage- 14/7/03	—	100,000 N.R.	10 not 100	
3112A Settled sewage 4/3/03	100,000 (— indol) (+ clot)	100,000 N.R. 100,000 B.S. 100,000 In.	100 not 1,000	
3183 Settled sewage 8/7/03	—	100,000 N.R.	10 not 100	
3191 Settled sewage 14/7/03	—	100,000 N.R.	100 not 1,000	

Although the sewage was at the time mainly a slop water sewage, the bacteriological results are very similar to those obtained in the case of water closet sewage.

On the assumption that the neutral red broth, bile salt glucose peptone, lactose peptone milk and indol tests yield somewhat parallel results to the B. coli test, in connection with the bacterioscopic analysis of sewage, it may be said that the raw sewage and settled sewage usually contained at least 100,000 B. coli or coli-like microbes per c.c. The B. enteritidis sporogenes test gave a positive result either with $\frac{1}{10}$th or $\frac{1}{100}$th of a cubic centimetre.

PRIMARY CONTACT BEDS.

Number of beds	4.
Size of each (roughly)	28 feet by 16 feet by 4 feet 3 inches deep.
Area (total)	199 square yards.
Cubic content (total)	282 cubic yards.

Construction.—Excavation in clay formation. Banks formed of material excavated. Clay bottom laid with 4-inch drain pipes in herring-bone formation, falling to one outlet valve in the corner of each bed.

Distribution.—One wooden trough extending down the centre for the whole length of the bed.

Material.—Coke, clinker and stone, graded as follows:—Top—9 inches coke under 1″ diameter; Middle—2 feet 9 inches clinker, 1″ to 2″ diameter; Bottom—9 inches stone, $1\frac{1}{2}$″ to 2″ diameter.

Age.—The beds were three years old when the observations began.

Working.—From 6 a.m. to 10 p.m. the beds were filled in simple rotation, but from 10 p.m. to 6 a.m. the settled sewage was allowed to flow into one bed, and if that filled, to pass over its surface, into another bed, and so on. On a wet night all the beds would become full, and would consequently have to be filled again the next morning without having had a proper rest, but as a rule only two beds were filled in the night.

Capacity—The original total empty tank capacity of the four primary beds was roughly 47,600 gallons. Assuming that the material when first put in would occupy half the tank space, the original water capacity would be approximately 23,800 gallons.

At our first measurement, on May 28th, 1902, at the start of our work, the beds being then 3 years old, the total capacity of the four beds was 11,945 gallons or 25 per cent. of the original empty tank capacity, by this time, therefore, the beds had lost about 50 per cent. of their assumed water capacity.

After having dealt with 11,466,256 gallons (4,673 fillings in 276 days, equivalent to 4·3 fillings per 24 hours), the capacity on March 4th, 1903, was found to be 7,689 gallons, or 16 per cent. of the original empty tank capacity, the beds being in a very clogged and sodden condition and incapable of doing regular work.

On continuing from March 4th to May 20th, 1903, and giving all the primary beds a complete rest for four weeks in May, the capacity rose to 9,335 gallons, or 19·6 per cent. of the original empty tank capacity. The rate of treatment during this time was equivalent to 3·4 fillings per 24 hours.

But the greater part of the capacity thus regained was rapidly lost in a short period of further treatment, from May 20th to July 9th, 1903, when 1,721,714 gallons of settled sewage (781 fillings in 50 days, equivalent to 3·9 fillings per 24 hours) were treated. The capacity on July 9th was 8,300 gallons, or 17·2 per cent. of the original empty tank capacity, the beds being by this time very clogged and sodden again.

Primary effluents.—Of these, three ordinary chance samples, Nos. 3037, 3111A and 3161A, and one experimental sample, No. 3160, were examined partially. The three ordinary samples varied appreciably in composition, *e.g.*, the 4 hours' "oxygen absorbed" figures were 3·64, 1·85 and 2·66. No one of them contained any oxidised nitrogen to speak of, and none of them withstood incubation. The centrifuge figures—40, 26 and 37=a mean of 34—would represent something like three parts of suspended solids per 100,000.

These primary beds have, therefore, effected a great purification, though of course an insufficient one, regarded from the point of view of a well oxidized final effluent. Thus, taking the four hours' "oxygen absorbed" figures, we have: settled sewage (3 sets of hourly samples), 8·33; primary effluents (3 chance samples) 2·72. This is, however, not a true comparison, as the samples were not corresponding ones, and the conditions of weather, etc,, were different,

Sample No. 3160 is instructive. It represents a flush-out from a three-quarters' empty primary bed, which had been resting for four weeks. This flush brought out an enormous quantity of suspended solids—409 parts per 100,000, of which 193 parts were volatile on ignition.

Bacteriological Notes.—For results see under Secondary contact bed effluents.

SECONDARY CONTACT BEDS.

Number of beds - - - -	5.
Size of each bed - - - -	28 feet by 21 feet 6 inches by 3 feet 3 inches deep.
Area (total) - - - - -	334 square yards.
Cubic content (total) - - -	365 cubic yards.

Construction.—Three sides brick-walled, the fourth being formed in the clay. The floor of each bed is of concrete, overlaid with 4-inch agricultural drain pipes, jointed and in herring-bone formation and falling to a valve at the end of each bed.

Distribution.—One wooden trough extending down the centre for the whole length of the bed.

Material.—Coke graded as follows :—Top—2 feet 3 inches coke breeze, $\frac{1}{4}$ inch to $\frac{3}{4}$ inch diameter; bottom—1 foot coke breeze, 1 inch to 2 inches diameter.

Age.—The beds were first used in August, 1901, and were 9 months old when we commenced our work at Halton.

Working.—No particular method of working these secondary beds was followed. They were filled (mostly in the day hours) whenever there was any primary effluent to run off, and when there was an increased flow of sewage which the primary beds were unable to cope with, they were filled with settled sewage.

This treatment of settled sewage on the secondary beds happened often. Thus we observed that from May 29th, 1902, to March 4th, 1903, the secondary beds received about 7,500,000 gallons of settled sewage, which means that for every 2 volumes of primary effluent the secondary beds treated 1 volume of settled sewage.

It will be seen that this method of working the secondary beds had an adverse effect upon their water capacity and also upon the final effluent. It is certain, also, that the long contact (4 hours) found necessary to obtain clear effluents from such coarse secondary beds, combined with the frequent fillings given to them, was a contributory cause to their ultimate loss of capacity.

Capacity.—The original total empty tank capacity of all the secondary beds was 61,140 gallons. After the beds were filled with material, their capacity would be reduced to about 50 per cent., *i.e.*, to 30,570 gallons approximately.

At our first measurement, on May 29th, 1902, of bed No. 5, taken as typical of the rest, the capacity was 20,575 gallons, or 33 per cent. of the original empty tank capacity. At this time the secondary beds were 9 months old and had been treating chiefly primary bed effluent.

On March 4th, 1903, after all the 5 secondary beds had treated about 18,988,000 gallons (4,470 fillings in 277 days, equivalent to 3·2 fillings per 24 hours) of primary bed effluent and settled sewage, the capacity was found to be 21,900 gallons, or 35 per cent. of the original empty tank capacity. As regards this measurement, however, we know that it was too high owing to a leak in the bed; still, there was no doubt that at this time the beds had not lost capacity to any appreciable extent.

On July 9th, 1903, however, at the end of a second and very heavy period of treatment, during which about 12,390,000 gallons (3,231 fillings in 127 days, equivalent to 5·08 fillings per 24 hours) of mostly settled sewage were dealt with, the capacity had fallen to 16,450 gallons or 26·9 per cent. of the original empty tank capacity.

Amount treated upon the Filters.—On a dry weather flow of 35,000 gallons per 24 hours, the amount treated per cube yard per 24 hours would be 54 gallons. The year during which we made our observations, however, was an exceptionally

wet one, and on the observed total of 68,550 gallons of settled sewage treated per day between May 29th, 1902 and March 4th, 1903, we find that the actual amount treated per cube yard per 24 hours was 106 gallons. Probably, in an ordinary year, about 80 gallons per cube yard per 24 hours would be about the amount treated.

Secondary Effluents.—Five ordinary samples, drawn in November, 1902, and in March, June and July, 1903 (in addition to four experimental ones) were examined chemically, viz., No. 3038, 3111B, 3161B, 3187 and 3189), with the following results :

	Parts per 100,000	Average.	Number of Estimations.
Ammoniacal Nitrogen	(0·77 and 2·30)	—	(2)
Albuminoid Nitrogen	(0·16 and 0·29)	—	(2)
Oxidized Nitrogen (approximate figures)	(0·73 to 1·23)	0·88	(5)
"Oxygen absorbed" at 27° C. (80° F.) at once	(0·43 to 1·09)	0·77	(5)
,, ,, ,, ,, ,, in 4 hours	(1·17 to 3·72)	2·67	(5)
Solids by centrifuge (vols.)	(12·0 to 51·0)	34·0	(5)
Incubator test (by smell)	− 1 +; 1 (?); 3 −	—	(5)
Smell of sample when drawn	− 4 +; 1 (?)	—	(5)
Smell of sample when analysed	5 +	—	(5)

It will be noted that all the above samples had a clean smell when analysed, but that three out of the five failed to withstand the incubator test, although there was in all of them a fair quantity of nitrate. The suspended solids, as judged by the centrifuge figures, were, however, rather too large, excepting in Nos. 3038 and 3111B. No. 3189, which was an average sample of the first emptying for the day, and which was drawn in 17 fractions, evidently suffered from the admixture of the last two of these fractions, which contained much matter in suspension.

These effluents therefore require a somewhat greater purification, including the settlement of suspended solids, to bring them within a reasonable standard of purity.

Bacteriological Notes.—As the total number of samples examined was not very numerous and as the secondary effluents were not much, if at all, better bacteriologically than the primary contact bed effluents, all the results as regards effluents are grouped together in one table :—

RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF SAMPLES OF PRIMARY AND SECONDARY CONTACT BED EFFLUENTS OBTAINED FROM HALTON.

Description of the Sample.	Number of B. coli (or gas forming coli-like microbes.)	B.S.=Bile-salt glucose peptone test. N.R.=Neutral red broth test. In.=Indol test. L.P.M.=Lactose peptone milk test.	B. Enteritidis sporogenes test.	Remarks.
A. Primary contact bed effluent, 23/5/02.	1,000 not 10,000 (+ indol) (+ clot)	1,000 not 10,000 N.R. 1,000 not 10,000 B.S. 1,000 not 10,000 In. 10,000 not 100,000 L.P.M.	1 not 10	A. "Gas" test + ·1 c.c. (24 hours.)
B. Primary contact bed effluent, 26/5/02.	10,000 not 100,000 (+ indol) (− clot)	100,000 N.R. 10,000 not 100,000 B.S. ,000 not 10,000 In. 10,000 not 100,000 L.P.M.	100 not 1,000	B. "Gas" test + ·01 c.c. (24 hours.)
C. Primary contact bed effluent, 28/5/02.	10,000 not 100,000 (− indol) (+ clot)	100,000 N.R. 10,000 not 100,000 B.S. 1,000 not 10,000 In. 10,000 not 100,000 L.P.M.	100 not 1,000	C. "Gas" test + ·01 c.c. (21 hours.)
3037. Primary contact bed effluent, 3/11/02.	—	100,000 L.P.M.	100 not 1,000	3037. 2,450,000 microbes. (agar at 37° C.)

Results of the Bacteriological Examination of Samples of Primary and Secondary Contact Bed Effluents obtained from Halton—*cont.*

Description of the Sample.	Number of B. coli (or gas forming coli-like microbes.	B.S.=Bile salt glucose peptone test. N.R.=Neutral red broth test. In.=Indol test. L.P.M.=Lactose peptone milk test.	B. Enteritidis sporogenes test.	Remarks.
3111A. Primary contact bed effluent, 4/3/03.	100,000 (+ indol) (+ clot)	1,000 not 10,000 N.R.	10 not 100	—
3091A. (Experimental sample mixed tank liquor and primary bed effluent, 19/1/03).	—	10,000 not 100,000 N.R.	10 not 100	**3091A.** Total number of microbes : 1,700,000 (gelatine at 20° C.) 400,000 (agar at 37° C.) "Gas" test + ·1 c.c. (24 hours.) "Gas" test + ·001 c.c. (48 hours.) "Gas" test + ·0001 c.c. (72 hours.)
(*a*) Secondary contact bed effluent, 23/5/02	1,000 not 10,000 (+ indol) (+ clot)	1,000 not 10,000 N.R. 10,000 not 100,000 B.S. 10,000 not 100,000 In. 10,000 not 100,000 L.P.M.	1 not 10	(*a*) "Gas" test + ·1 c.c. (24 hours.)
(*b*) Secondary contact bed effluent, 26/5/02	100,000 (– indol) (– clot)	10,000 not 100,000 N.R. 100,000 B.S. 1,000 not 10,000 In. 100,000 L.P.M.	10 not 100	(*b*) "Gas" test + ·01 c.c. (24 hours.)
(*c*) Secondary contact bed effluent, 27/5/02	100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R. 10,000 not 100,000 B.S. 10,000 not 100,000 In. 10,000 not 100,000 L.P.M.	100 not 1,000	(*c*) "Gas" test + ·01 c.c. (24 hours.)
d) Secondary contact bed effluent, 28/5/02	100,000 (– indol) (– clot)	100,000 N.R. 100,000 B.S. 10,000 not 100,000 In. 100,000 L.P.M	10 not 100	"Gas" test + ·01 c.c. (24 hours.)
3038. Secondary contact bed effluent, 3/11/02.	—	100,000 L.P.M.	100 not 1,000	Total number of microbes :— 870,000 (agar at 37°C.)
3091B. Secondary contact bed effluent, 19/1/03.	—	100,000 N.R.	10 not 100	**3091B.** Total number of microbes :— 110,000 (agar at 37°C). 370.000 (gelatine at 20°C.) "Gas" test + ·1c.c. (24 hours). "Gas" test + ·01 c.c. (48 hours.) "Gas" test + ·001 c.c. (72 hours.)
3111B. Secondary contact bed effluent, 4/3/03.	10,000 not 100,000 (+ indol) (+ clot)	100,000 N.R. 10,000 not 100,000 B.S. 10.000 not 100,000 In.	10 not 100	
3112B. Secondary contact bed effluent, 4/3/03.	1,000 not 10,000 (+ indol) (+ clot)	1,000 not 10,000 N.R. 10,000 not 100,000 B.S. 1,000 not 10,000 In.	1 not 10	
3187. Secondary contact bed effluent, 13/7/03.	—	100,000 N.R.	100 not 1,000	
3188. Secondary contact bed effluent, 13/7/03.	—	100,000 N.R.	10 not 100	
189. Secondary contact bed effluent, 13/7/03.	—	100,000 N.R.	10 not 100	

It will be noted that the secondary effluents were not much, if at all, better bacteriologically than the primary effluents. This result is doubtless to be ascribed to the fact that settled sewage was not uncommonly treated on the secondary beds, and that the material filling the beds was relatively coarse.

Taking, therefore, the primary and secondary effluents (both ordinary and experimental) together, it may be noted that the number of B.coli or coli-like microbes ranged from 1,000 to 100,000 per c.c. Considering the neutral red broth, indol, bile-salt glucose peptone and lactose peptone milk tests together, these tests yielded positive results with from $\frac{1}{1000}$ to $\frac{1}{100000}$ of a cubic centimetre. With the exception of the three samples, A, (a), and 3112B (+1c.c. ; −·1c.c.), all the effluents yielded positive results with from $\frac{1}{10}$ to $\frac{1}{1000}$ of a cubic centimetre with the B. enteritidis sporogenes test.

The secondary effluents were unsatisfactory from the bacteriological point of view.

Experimental Secondary Effluents.—In addition to the ordinary secondary effluents, four experimental ones were drawn (or five, if we include No. 3038).

Of these, No. 3091B, an effluent resulting from the treatment on the secondary bed of a mixture of streaming primary effluent and settled sewage, was of fair quality and withstood incubation; it contained practically no suspended solids (about 1 part per 100,000).

No. 3112B, representing a final effluent of 2 hours' single contact in a secondary bed, after the bed had had a rest of 24 hours, was of poor quality, though it probably withstood incubation (solids about 2 parts). Compared with the settled sewage run into the bed on this occasion, the effluent showed only a moderate purification.

No. 3188 was the first flush of the emptying represented by the ordinary sample, No. 3187. It did not differ in any material respect from 3187 and was a poor sample, failing to withstand incubation.

Nos. 3038 and 3227 were drawn in order to test the effect of 4 hours' contact on the secondary beds. No. 3038 was of indifferent quality and failed upon incubation, though it contained little suspended solid ; and the same applies to No. 3227, excepting that there were rather more suspended solids in it. The longer contact had evidently been of no benefit to the effluent, but rather the reverse, from the reducing action of the accumulated organic matter in the filter bed. This system of 4 hours' contact had been going on before the drawing of No. 3227 for a fortnight, at least, with probably four fillings a day during that time.

One feature running through all the secondary effluents excepting No. 3227 (which contained no oxidized nitrogen) was that the amount of oxidized nitrogen was pretty constant in all of them, amounting to nearly 1 part per 100,000, approximately, and constituting about one-third of the total nitrogen present.

Effect of Temperature on the Process.—On one occasion, when some snow was melting on the roads, we found the final effluent with a temperature as low as 5·5° C., the sewage temperature being also low. As a general rule the temperature of the final effluent followed that of the sewage. Our observations on this point showed that the process did not suffer any derangement from temperature variations in the atmosphere or the sewage.

Temperature measurements of the atmosphere, sewage, settled sewage and effluents were taken at each of our visits to the works and also every few hours over a period of (1) 48 hours, and (2) 24 hours in July, 1903.

Length of Contact in the beds.—Owing to the pressure of work put upon the primary beds, the length of contact in these varied greatly. Sometimes at night the sewage liquor was held up for as long as 8 or 10 hours, while in the day time it was usually from 1 and 2 hours in the beds. Our samples of primary bed effluent were all taken in the daytime. The contact in the secondary beds was 1 or 2 hours for the greater part of our observations, but towards the end we increased it to 4 hours, in order to see if a better final effluent could be obtained.

SUMMARY.

The sewage is of about medium or rather under medium strength and the settled sewage still contains about 11 parts of suspended solids per 100,000.

The beds, both primary and secondary, are of coarse material. Owing to their comparatively small area and to the large volume of sewage treated on them (normally four fillings per day, but frequently six or seven), they were much overworked.

The great decrease in capacity of the primary beds, within the short period of 4 years, is sufficient evidence of those beds having had too much to do. The secondary beds, on the other hand, maintained their capacity well until they were called upon to act as primary beds, *i.e.*, to treat settled sewage.

Had the primary beds been of sufficient size to treat the settled sewage at the rate of two fillings a day in dry weather (which would mean three or four fillings in wet weather), and had the secondary beds been of finer material and sufficiently large to treat the primary effluent at the rate of three fillings a day in dry weather, we think that a satisfactory final effluent would have been obtained, and that the beds would have lasted for a reasonable number of years. As it was, the final effluent, after double contact, could not be regarded as satisfactory, either chemically or bacteriologically; it ought, however, to be borne in mind here that the frequent treatment of settled sewage upon the secondary beds must undoubtedly have had something to do with this result.

We do not consider that the construction of the beds was satisfactory. Towards the end of the period of our observations, the primary beds leaked so badly into one another that at least two had to be filled at the same time; the banks had also sunk a great deal; we have therefore been led to the conclusion that the subsoil at Halton is not of a sufficiently clayey nature to allow of the proper construction of contact beds without the use of building material.

No observations upon the Whitebeck were made, owing to the fact that the effluent from the filter beds is passed over land before being discharged.

We should like, in conclusion, to express our thanks to Mr. W. B. Pindar, Clerk to the Rural District Council, Mr. S. Shaw, M.I.C.E., the Engineer who designed the Works, and Mr. R. Adamson, Manager of the Sewage Works, for much assistance given to us in connection with the observations.

HAMPTON SEWAGE WORKS.

(HAMPTON URBAN DISTRICT COUNCIL).

1. Situation of works - - - - - -	About $1\frac{1}{2}$ miles from the populous part of Hampton.
2. Method of treatment - - - - -	Triple contact filtration of crude sewage.
3. Population draining to works during observations	6,500 (estimated average).
4. Water supply in gallons per head and whence obtained - - - - - - -	32; Grand Junction District Waterworks Company (now Metropolitan Water Board)—a rather hard water.
5. Number of W.C's - - - - - -	2,000.
6. Sewerage system - - - - - -	Separate.
7. Average dry weather flow of sewage in gallons per 24 hours - - - - - -	180,000 (estimated average).
8. Gallons of sewage per head per day - - -	27·7.
9. Character of the sewage - - - - -	Strong domestic sewage.
10. Period of observations - - - - -	June, 1902 to December, 1904.
11. Age of beds - - - - - - -	About 3 years.
12. Amount of storm water treated - - -	Practically no storm water finds its way into the sewers, except in times of prolonged and heavy rainfall.
13. Total area of filters in yards square - -	3,373.
14. Total cubic content of filters in yards cube -	4,195.
15. Nature of filtering medium—	
(*a*) Primary beds - - - - -	Boiler furnace clinker, everything over $\frac{3}{4}$ inch (average 2 inches).
(*b*) Secondary beds - - - - -	Boiler furnace clinker, $\frac{1}{4}$ inch to $\frac{3}{4}$ inch.
(*c*) Tertiary beds - - - - -	Boiler furnace clinker, everything under $\frac{1}{4}$ inch, including dust.
16. Gallons of crude sewage treated per square yard per 24 hours (all filters included) -	53·4
17. Gallons of crude sewage treated per cube yard per 24 hours (all filters included) - -	43·0
18. The final effluent is discharged into - - -	The river Thames, near Hampton Court.

FLOW OF SEWAGE.

The sewers are entirely separate from the surface water drains, and the subsoil water is carried away by pipes laid underneath the sewers proper. Excepting in times of prolonged and heavy rainfall, practically no storm water finds its way into the sewers.

Owing to the ejectors, the Hampton sewage reaches the works in flushes, and consequently it was found impracticable to measure the flow by means of a weir and an automatic recorder; the records of bed fillings had therefore to be relied upon for an estimate of the sewage flow. With new beds, this method of gauging would probably be accurate, but the Hampton primary beds were more or less clogged during the observations, and the estimates of the sewage flow are therefore only approximate.

During a dry week in July, 1902, shortly after the first measurement of capacity was made, the bed fillings showed a dry weather flow of 140,000 gallons per day; while for a similar week in July, 1904, but some time away from any capacity gauging, the flow was about 160,000 gallons per day. From the total number of bed fillings between June, 1902 and February, 1903, the average daily flow was 140,000 gallons; and, from February, 1903 to November, 1904, 186,000 gallons.

Based on the water supply per head of the population, the dry weather flow in 1902 was approximately 160,000 gallons per day, and, the population having increased, in 1904 approximately 200,000 gallons per day. In our calculations for the quantity treated in dry weather, we have taken 180,000 gallons as the approximate average dry weather flow.

There appears to be only a small quantity of subsoil water gaining access to the sewers in dry weather.

Screens and Detritus Tanks.—The sewage passes through a half-inch screen before reaching the primary beds, and then through shallow settling ponds called "Bays," formed on part of the surface of each primary bed at the inlet end.

Crude Sewage.—Three sets of hourly samples, Nos. 1, 2, and 3, drawn in dry and very warm weather in June, 1902, were examined, in addition to three chance samples. Owing to the system followed, the hourly fractions of these sets could not be drawn in the usual way, according to rate of flow, but they had to be taken in equal quantities every hour, omitting those hours at which no sewage was arriving at the works.

The *hourly samples* were of very even composition and gave the following figures on analysis:—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(8·56 to 10·61)	9·40	(3)
Albuminoid Nitrogen	(1·33 to 1·42)	1·38	(3)
Total Organic Nitrogen	(2·81 to 3·57)	3·14	(3)
Total Nitrogen	(12·08 to 13·42)	12·54	(3)
"Oxygen absorbed" at 27° C. (80°F.) *at once*	(4·71 to 5·30)	5·06	(3)
,, ,, ,, ,, *in 4 hours*	(16·55 to 19·81)	17·82	(3)
Chlorine	(13·0 to 16·28)	15·15	(3)
Solids in suspension	(47·5 and 49·5)	48·5	(2)
Solids by centrifuge (vols.)	(268 to 345)	326·0	(3)
Ratio of solids in suspension to centrifuge solids	(1 : 7·7 and 1 : 7·0)	1 : 7·4	(2)
"Cellulose" (by alkali, acid and ether)	(6·68 to 7·84)	7·13	(3)
Ratio of "cellulose" to solids in suspension	1 : 7·1 and 1 : 6·3)	1 : 6·7	(2)

These figures show the sewage to be a very strong one in every respect.

The three *chance* samples, Nos. **3093A**, **491** and **645**, were taken on three forenoons in the months of January, March and December, the last of them on a wet day. Practically speaking, they were only half the strength of the hourly samples drawn in the month of June, as will be seen from the following figures of analysis. Allowing for the fact of sewage in general being less concentrated in winter than in summer, this difference in strength is instructive, as showing that the weaker sewage at Hampton comes to the works in the daytime,—the converse of what usually obtains. These chance samples gave the figures :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - - - - -	(4·25 and 5·78)	5·02	(2)
Albuminoid Nitrogen - - - - - - - -	(0·78 and 0·85)	0·81	(2)
Total Organic Nitrogen - - - - - - -	(1·67 and 1·96)	1·82	(2)
Total Nitrogen - - - - - - - -	(4·91 to 7·74)	6·19	(3)
"Oxygen absorbed" at 27° C. (80°F.) *at once* - - -	(1·62 to 2·76)	2·34	(3)
" " " " *in 4 hours* - -	(7·06 to 9·91)	8·46	(3)
Chlorine - - - - - - - - - - - - -		7·60	(1)
Solids in suspension - - - - - - - -	(19·3 and 20·4)	19·9	(2)
Solids by centrifuge (vols.) - - - - - -	(119 to 186)	152·0	(3)
Ratio of solids in suspension to centrifuge solids -	1 to 9·1 and 1 : 8·3	1 : 8·7	(2)

Bacteriological Results.—The bacteriological results are set forth in the following table. Three out of the four samples contained 1,000 spores of B. enteritidis sporogenes per c.c. The B. coli test and presumptive tests for B. coli yielded comparable results—all the samples gave a positive result with ·00001 c.c. (100,000 per c.c.)

Description of the Sample.	Number of B. coli (or gas-forming coli-like microbes).	B.S. = Bile salt glucose peptone test. N.R. = Neutral red broth test. In. = Indol test. L.P.M. = Lactose peptone milk test.	B. Enteritidis sporogenes test.	Remarks.
1. Crude Sewage, average sample 20/6/02	100,000 (+indol) (+clot)	100,000 In. 100,000 N.R. 100,000 L.P.M. 100,000 B.S.	1,000 not 10,000	"Gas test" +·001 c.c. 24 hours at 20°C.
2. Crude Sewage, average sample 22/6/02	—	100,000 L.P.M. 100,000 B.S.	—	"Gas" test +·001 c.c. 24 hours at 20°C.
3. Crude Sewage, average sample 24/6/02	100,000 (+indol) (+clot)	100,000 In. 100,000 N.R. 100,000 L.P.M. 100,000 B.S.	1,000 not 10,000	"Gas" test +·001 c.c. 24 hours at 20°C.
3093A. Crude sewage, chance sample 29/1/03	—	100,000 N.R. 100,000 B.S.	100 not 1,000	7 million microbes per c.c. (gel. at 20°C.) "Gas" test + ·01 c.c. 24 hrs. at 20°C.
491 Screened sewage 11/3/03.	—	100,000 N.R.	1,000 not 10,000	

FILTER BEDS.

PRIMARY BEDS.

Number of Beds - - -	5.
Size of each - - - -	50 feet 6 inches by 34 feet 6 inches.
Total area - - - - -	967 square yards.
Depth of material - - -	4 feet.
Total cubic content - - -	1,289 cubic yards.
Distribution - - - -	None.
Material - - - - -	Boiler furnace clinker (local), consisting of everything over 1 inch diameter.
Construction - - - -	Cement concrete throughout.
Underdraining - - - -	16 half channels formed in the concrete floor, covered with 6-inch perforated tiles. These connect with a main channel, which extends from side to side at the outlet end.

Working.—The method of working the primary beds during our observations was to have four in use and one resting; four beds, therefore, constituted the working set. When first started, the primary beds were filled not more than once a day, and the sewage was given a full two hours' contact. At the commencement of the observations, in June, 1902, the primary beds were receiving on an average $2\frac{1}{2}$ fillings* per day, with a two hours' contact, but towards the end (December, 1904), the number of fillings had increased to an average of $3\frac{1}{2}$ per day, and the contact lasted only half an hour. This was due mainly to the loss of capacity in the beds, but also to some extent to the increase in the flow of sewage. The time taken to fill the beds has also varied, but during the observations it was on the average about half an hour.

Age.—The beds were first used regularly in the early part of 1899.

Capacity.—The original empty tank capacity of the five primary beds was 217,519 gallons; assuming that the material when first put in would occupy half this space, the original water capacity of the five beds would be 108,759 gallons.

The observations commenced in June, 1902, with a measurement of the primary bed capacity. Beds Nos. 2 and 3 were taken as typical of all the primary beds, and from their measurement we estimated that the total primary bed capacity at this time was 59,000 gallons.

The primary beds, therefore, although they were constructed to deal with 210,000 gallons of sewage per day (*i.e.* about two fillings for each bed per day), were reduced after three years' work to about 27 per cent. of the original empty tank capacity, or 54 per cent. of the original water capacity. From this time onward, owing to the clogged condition of the surfaces, they were worked only with difficulty; but by careful filling, by the settlement of as much suspended matter as possible in the "bays," and by the removal of sludge from the "bays," and the cleaning and forking of the bed surfaces about every three weeks, the beds were kept going for a further period of $2\frac{1}{2}$ years, without, as will be seen, much further loss of capacity. At one time, however, one of the primary beds was reduced to 16 per cent. of its original empty tank capacity.

From June, 1902, when the primary bed capacity was about 59,000 gallons, to February, 1st, 1903, the date of the second measurement, the beds treated partially settled sewage at an average rate of 2·5 fillings for each bed per day. This second measurement gave the total capacity as 47,590 gallons, or 21·8 per cent. of the original total empty tank capacity.

* This average, like all other averages for bed fillings, is obtained by dividing the total number of fillings by the total number of filters. Since, however, one of the primary beds at Hampton is usually being rested for surface cleaning, the actual average number of fillings for the four beds at work is proportionately greater.

In the second period, which lasted from February 1st, 1903, to November 8th, 1904, the primary beds treated partially settled sewage at an average rate of 3·52 fillings for each bed per day. At the end of this period, the primary bed capacity was found to be 58,000 gallons, or 26·6 per cent. of the original total empty tank capacity, the increase in capacity being due to the lighter work given to the beds during the dry summer of 1904, and to the regular cleaning of the surface material.

Primary Effluents.—Only three samples of Primary Effluent, Nos. 3033, 3093B and 3354, were examined chemically, two of them partially; they were drawn in the months of January and October, and at mid- or three-quarters-flow. Only a few figures of analysis need therefore be given here.

	Parts per 100,000.	Average.	Number of Estimations.
Total Nitrogen	(3·99 and 2·87)	3·43	(2)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(0·82 to 1·12)	0·97	(3)
,, ,, ,, ,, *in 4 hours*	(2·94 to 4·08)	3·58	(3)
Solids by centrifuge (vols.)	(15 to 52)	34·0	(3)
Incubator test (by smell)		3 failed *	(3)
Smell when drawn		3 bad	(3)
Smell when analysed		2 good 1 bad	(3)

* Assumed in the case of No. 3033.

For one contact of a strong sewage, the above results show a good purification. Two of these effluents had a strong earthy, *i.e.*, a clean, smell when they came to be analysed, and one of them, at all events, still contained a little oxidized nitrogen. The figures for total nitrogen, "oxygen absorbed" from permanganate, and centrifuge are all low, comparatively speaking. The suspended solids would amount to about 4 parts per 100,000. It could not, of course, be expected that these primary effluents would withstand incubation.

As compared with the hourly samples of sewage examined, these primary effluents shewed the following percentage reduction (there can, however, be little doubt that the sewage from which these effluents were derived was weaker than the hourly samples):—

	Calculated on the Hourly Samples of Sewage.
"Oxygen absorbed" *at once*	81 per cent reduction
"Oxygen absorbed" *in 4 hours*	80 ,, ,,

Bacteriological results.—The bacteriological results are given in the accompanying table. The effluents were unsatisfactory from the bacteriological point of view. The B. coli test and the presumptive tests for B. coli gave a positive result with ·00001 c.c. (100,000 per c.c.). The B. enteritidis sporogenes test yielded a positive result with ·01 c.c. (100 per c.c.). Sample 3093B contained over 6½ million microbes per c.c.

Description of the Sample.	Number of B. coli (or gas-forming coli-like microbes).	B.S. = Bile-salt glucose peptone test. N.R. = Neutral red broth test. In = Indol test. L.P.M. = Lactose peptone milk test.	B. enteritidis sporogenes test.	Remarks.
Primary bed effluent, chance sample, 22/6/02.	—	100,000 L.P.M. 100,000 B.S.	—	"Gas" test + ·01 c.c. 24 hours at 20°C.
3033. Primary bed effluent, mid-flow, 16/10/02.	100,000 (– indol) (– clot)	100,000 In. 100,000 N.R. 100,000 L.P.M. 100,000 B.S.	100 not 1,000	"Gas" test + ·01 c.c. 24 hours at 20° C.
3093B. Primary bed effluent, chance sample, 29/1/03.		100,000 N.R. 100,000 B.S.	100 not 1,000	"Gas" test + ·01 c.c. 24 hours at 20° C. 6,600,000 microbes per c.c. (gelatine at 20°C.)

SECONDARY BEDS.

Number of beds - - - - - -	5.
Size of each - - - - - -	57 feet 10 inches by 36 feet.
Depth - - - - - - -	4 feet.
Total area - - - - -	1,156 square yards.
Total cubic content - - - -	1,413 cubic yards. *
Distribution - - - - - -	4 beds are fed by unperforated half pipes, in herring-bone formation, and the fifth bed has a foot of fine material on the surface, which causes the on-flowing primary bed effluent to spread.
Material - - - - - -	Boiler furnace clinker (local), ¼ inch to ¾ inch diameter.
Construction - - - - - -	Cement concrete throughout.

Underdraining.—Sixteen half channels, formed in the concrete floor of the tank, covered with 6″ perforated tiles. These connect with a main channel, which extends from side to side at the outlet end of the tank.

Working.—When the observations commenced, in June, 1902, the secondary beds were being worked at a rate of rather less than 2½ fillings for each bed per day, with a contact lasting between one and two hours. The clogged condition of the primary beds and the consequent short contact given to them gradually affected the secondary beds, however, and by September, 1903, the average number of fillings to each secondary bed per day had risen to 2·89. Shortly after this, partly because of the loss of capacity in the secondary beds, and partly because of the continual filling and emptying of the primary beds, the method of using some of the secondary beds by "streaming" was resorted to occasionally, but only when it was impossible to get the primary bed effluent through the secondary beds in any other way. Eventually the material in the secondary beds was taken out and washed, and after this they were again worked strictly upon the contact plan.

Age.—The beds were first used regularly in the early part of 1899.

Capacity.—The original empty tank capacity of the five secondary beds was 239,625 gallons, and, on the assumption that the material occupied one-half of the space in the tank, the original water capacity was approximately 119,812 gallons.

Our first measurement (on No. 2 bed, taken as typical) was made on February 1st, 1903, after the beds had worked as contact beds for approximately four years. It gave 51,000 gallons as the total secondary bed capacity, equal to 21·5 per cent. of the original empty tank capacity.

After a further run of 16 months, sometimes of necessity as a streaming filter and sometimes as a contact bed, the capacity of No. 2 bed became so reduced that the material had to be taken out and washed. The bed had lasted, therefore, for rather more than five years.

After washing the material and replacing it, the bed was re-started on September 27th, 1904, and a measurement made ten weeks later gave its capacity as 19,900 gallons, equal to 41·3 per cent. of the original empty tank capacity, or 82·6 per cent. of the original water capacity. This measurement is interesting as showing that practically the whole water capacity can be regained by washing.

Secondary Effluents.—Eleven samples were examined chemically; excluding No. 492, which was drawn immediately the valve was opened, and which was therefore very impure (with no oxidized nitrogen and as much as 14 parts of suspended solids), the remaining ten samples may be divided into two groups, according as they were drawn when the secondary beds were used as contact beds proper or as streaming beds.

The first group (secondary *contact* bed effluents) comprises Nos. 3032, 3093c, 3147, 541, 3259 and 749. These were mostly taken in the spring and autumn months, in

* Allowing for batter on walls of tank.

varying weather. One of them was drawn with the bed one-third empty, another with the bed three-fourths empty, and the remaining four at mid-flow. They gave the following figures on analysis :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - - - -	(1·08 to 5·29)	2·51	(5)
†Albuminoid Nitrogen - - - - - - -	(0·23 to 0·39)	0·28	(3)
Oxidized Nitrogen - - - - - - - -	(0·19 to 2·35)	1·62	(5)
Oxygen absorbed from permanganate at— 26·7°C. (80°F.) *at once* - - - - - -	(0·44 to 1·10)	0·76	(6)
,, ,, *in 4 hours* - - - - -	(1·90 to 3·75)	2·79	(6)
Dissolved Oxygen taken up in 24 hours at about 18°C. (65°F.)* - - - - - - - - -	(0·39 to 1·42)	0·84	(4)
Solids by centrifuge (vols.) - - - - - -	(9·0 to 18·0)	14·0	(6)
Incubator test (Scudder) - - - - - - -		5 passed	(5)
Incubator test (by smell) - - - - - - -		4 passed 1 doubtful 1 failed	(6)
Smell when drawn - - - - - - - -		1 good 3 bad	(4)
Smell when analysed - - - - - - -		4 good 2 doubtful	(6)

* At laboratory temperature in two cases. † Probably rather high in Nos. 541 and 3259.

The above effluents varied in appearance from nearly clear and colourless to very turbid, though in no case were the suspended solids at all high (say 1 to 2 parts per 100,000, as judged by the centrifuge). Four of them had a clean smell when analysed, while four of the six—or possibly five—passed the incubator test.

Speaking generally, the effluents were not of high quality, and they varied considerably in composition. Two contacts of a strong crude sewage, therefore, as carried out at Hampton during our observations, were barely sufficient to turn out a satisfactory effluent, *per se*, chemically speaking.

As compared with the hourly samples of sewage, these chance samples of contact effluent showed the following percentage purification :—

Calculated on "oxygen absorbed" *at once* - 85 per cent.
,, ,, ,, ,, *in 4 hours* - 84 ,,

The second group (secondary *streaming* bed effluents) comprised Nos. 3355, 662, 698 and 3536. These were drawn at different seasons of the year and in dry or nearly dry weather. They were only partially analysed, but gave the following figures :—

	Parts per 100,000.	Average.	Number of Estimations.
Oxidized Nitrogen - - - - - - - -	(0·04 to 1·42)	0·62	(4)
"Oxygen absorbed" at 27°C. (80°F.) *at once* - - -	(0·92 to 1·83)	1·23	(4)
,, ,, ,, ,, *in 4 hours* - -	(3·42 to 7·55)	4·75	(4)
Dissolved Oxygen taken up in 24 hours at about 18°C. -	(1·18 to 1·43)	1·52	(3)
Solids in suspension - - - - - - - -	(5·1 and 11·8)		(2)
Solids by centrifuge (vols) - - - - - -	(37·0 to 154·0)	76·0	(4)
Ratio of solids in suspension to centrifuge solids	(1 : 11·6 and 1 : 13·27)	1 : 12·4	(2)
Incubator test (Scudder) - - - - - - -		2 passed	(2)
Incubator test (by smell) - - - - - - -		1 passed 1 doubtful 2 failed	(4)
Smell when drawn - - - - - - - -		3 bad	(3)
Smell when analysed - - - - - - -		3 good 1 doubtful	(4)

It is obvious from these figures that the streaming effluents *as a whole* were by no means so good as the contact ones, but here it must be borne in mind that the suspended solids averaged about 6 parts per 100,000, as against 1 to 2 in the contact

effluents. The presence of those solids of course raised the various figures of analysis, their influence being exemplified in No. 3536 (containing nearly 12 parts of solids), which was partially analysed both before and after filtration through paper. It gave :—

	Original Effluent.	Effluent after Filtration through paper.
Oxygen absorbed at 26·7°C. *at once* - - - - - - - - -	1·83	0·67
" " " *in 4 hours* - - - - - - - -	4·54	2·35
Dissolved Oxygen taken up in 24 hours at about 18°C. - - - - -	1·18	0·18

Had those effluents been settled, therefore, they would have shewn a marked improvement. Our general experience, however, leads us to the conclusion that, even with settlement, the Hampton streaming effluents could not have been considered sufficiently purified for a final effluent, judged by itself.

As compared with the hourly samples of sewage, these chance samples of streaming effluent show the following percentage purification :—

Calculated on " oxygen absorbed " *at once* - - 76 per cent.
" " " *in 4 hours* - - 73 "

Bacteriological Notes.—The bacteriological results are shewn in the accompanying table. Some of the effluents were drawn when the beds were being used as "streaming" filters. But even allowing for this, the bacteriological results were far from satisfactory. The B. coli test and presumptive tests for B. coli usually gave a positive result with ·00001 c.c. (100,000 per c.c.). The effluents contained 10 to 1000 (but usually 100) spores of B. enteritidis sporogenes per c.c. Nevertheless, it is worth noting that the percentage reduction of microbes in sample 3093c, which was comparative with sample 3093B (a primary effluent), was striking. The latter contained 6,600,000, and the former 1,800,000 bacteria per c.c., a reduction of 72 per cent.

Description of the Sample.	Number of B. coli (or gas-forming coli like microbes).	B.S.=Bile-salt glucose peptone test. N.R.=Neutral red broth test. In.=Indol test. L.P.M.=Lactose peptone milk test.	B. enteritidis sporogenes test.	Remarks.
Secondary bed effluent, chance sample, mid-flow, 22/6/02.		100,000 L.P.M. 100,000 B.S.	10 not 100	
3032. Secondary bed effluent, chance sample, mid-flow, 16/10/02.	100,000 (–indol) (–clot)	10,000 not 100,000 In. 100,000 N.R. 100,000 L.P.M. 10,000 not 100,000 B.S.	100 not 1,000	"Gas" test +·01 c.c. 24 hours at 20°C.
3093c. Secondary bed effluent, chance sample, mid-flow, 29/1/03.		10,000 not 100,000 N.R. 10,000 not 100,000 B.S.	10 not 100	"Gas" test + ·1 c.c. 24 hours at 20°C. 1,800,000 microbes per c.c. (gelatine at 20°C.)
492. Secondary bed effluent, chance sample, first runnings, 11/3/03.	100,000 (–indol) (–clot)	100,000 In. 100,000 N.R. 10,000 not 100,000 L.P.M.	100 not 1,000	
3147. Secondary bed effluent, chance sample, bed three-fourths empty, 7/5/03.		10,000 not 100,000 N.R.	100 not 1,000	
541. Secondary bed effluent, bed one-third empty, 2/6/03.		100,000 N.R.	100 not 1,000	
662. Secondary bed effluent, streaming effluent, 1/2/04.	10,000 not 100,000 (–indol) (+clot)	10,000 not 100,000 N.R.	1,000 not 10,000	
698. Secondary bed effluent, streaming effluent, 30/5/04.	100,000 (+indol) (+clot)	100,000 N.R. 100,000 B.S.	100 not 1,000	
3536. Secondary bed effluent, streaming effluent, 15/8/04.	100,000 (+indol) (+clot)	100,000 N.R. 100,000 L.P.M. 100,000 B.S.	1,000 not 10,000	
749. Secondary bed effluent, mid flow, 10/11/04.	100,000 (+indol) (+clot)	100,000 N.R. 100,000 B.S.	100 not 1,000	

TERTIARY BEDS.

Number of beds - - -	- 5.
Size of each - - - -	- 62 feet 6 inches by 36 feet.
Total area - - - -	- 1250 square yards.
Depth of material - - -	- 4 feet.
Total cubic content - -	- 1493 cube yards.
Material - - - - -	- Boiler furnace clinker (local), consisting of everything under ¼ inch diameter, including dust.
Construction - -	- Cement concrete throughout.
Distribution - -	- By means of grips in the material.
Underdraining - -	16 half channels, formed on the concrete floor and covered with 6-inch perforated tiles. These connect with a main channel, extending from side to side at the outlet end of the tank.

Working.—The tertiary beds were worked as contact beds throughout the observations. At the commencement they were receiving on an average 2·2 fillings of secondary bed effluent per day, and at the end 2·8 fillings per day. The length of contact in the tertiary beds was about two hours, throughout the observations. Since the observations were completed, in December, 1904, some of the tertiary beds have been used as streaming filters, owing to the fact that the material had become rather consolidated, and it was therefore difficult to fill them.

Age.—The beds were first regularly used in the early part of 1899.

Capacity.—The original total empty tank capacity of the five tertiary beds was 251,944 gallons, and, assuming that the material occupied one half of the space, the original water capacity of the tertiary beds was about 125,972 gallons. We were able to measure the capacity of one of the tertiary beds (No. 2) only once—in December 1904, when the bed had been at work for five years. The rate of filtration since it was brought into use in 1899 had gradually increased up to this time, being less than one filling per day in 1899, 2·43 fillings per day between June, 1902, and February, 1903, and 3·33 fillings per day between February, 1903 and the end of the observations, in December, 1904. The average rate of filtration during the whole of the observations was 2·99 (say, 3) fillings per day.

The measurement gave the capacity of the five tertiary beds at this time as 65,835 gallons, or 26·1 per cent. of the original empty tank capacity. The actual capacity of No. 2 bed, as measured, was 13,167 gallons.

During April, 1905, the material in this bed was turned over, in order to see if the capacity could be regained, and after a further run of about one month the bed was again measured. The capacity on this occasion was 14,000 gallons. From the appearance of the material before it was turned over (although closely bound together, it was clean), it was thought possible that the greater part of the loss of capacity in the tertiary beds was due to consolidation of material rather than to clogging from suspended matter. It was expected, therefore, that the turning over would result in a considerable gain in capacity. Probably such very fine material as this occupies considerably more than 50 per cent. of the tank space,*and, if that be so, there could not have been at any time a great loss of capacity in the tertiary beds. On the other hand, it may have been that the capacity gained by the turning over was rapidly lost again when the beds were once more brought into use.

Tertiary Effluents.—Fifteen tertiary effluents were analysed chemically, most of them very fully. Twelve of these were, practically speaking, drawn at mid-flow, and therefore represented approximately the average working of the beds. Their numbers were 3034, 3093D, 482, 608, 3258, 644, 3356, 663, 673, 697, 3537 and 750. They gave the following results on analysis:—

* We think that it would be both interesting and useful if a number of exact measurements on a fairly large scale could be made with regard to this point, using material of various qualities and sizes.

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - - - - -	(0·11 to 1·49)	0·71	(9)
Albuminoid Nitrogen - - - - - - -	(0·05 to 0·19)	0·11	(8)
Oxidized Nitrogen - - - - - - - -	(1·93 to 3·12)	2·64	(12)
Total Nitrogen - - - - - - - - -	(3·95 to 4·37)	4·19	(4)
"Oxygen absorbed" at 27° C. (80° F.) *at once* - -	(0·09 to 0·53)	0·35	(12)
,, ,, ,, ,, *in 4 hours* - -	(0·77 to 1·71)	1·31	(12)
Dissolved Oxygen taken up in 24 hours at about 18°C.	(0·04 to 0·62)	0·38	(8)*
Chlorine - - - - - - - - - - -	(7·06 to 14·28)	11·14	(6)
Solids in suspension - - - - - - - -		Mere trace.	
Solids by centrifuge (vols.) - - - - - - -	(0·0 to 7·2)	1·2	(12)
Incubator Test (Scudder) - - - - - - -		10 or 11 passed 1 failed	(12)
,, ,, (by smell) - - -		12 passed	(12)
Smell when drawn - - - - - - - -		8 good	(8)
Smell when analysed - - - - - - - -		12 good	(12)
c.c. per litre. Oxygen in solution - - - - - - - - -	(0·0 to 1·5)	0·8 approx.	(9)

The ordinary samples of tertiary effluent examined were therefore all good or very good. They had all a clean smell when drawn, contained practically no solids in suspension, withstood the incubator test, and took up very little dissolved oxygen in 24 hours. By far the greater part of the nitrogen they contained was in the form of nitrate. Roughly speaking, about two-thirds of the original nitrogen in the sewage disappears during its passage through the three sets of contact beds.

The reduction in figures on the hourly samples of sewage is :—

Calculated on the Albuminoid Nitrogen - - -	92	per cent.
,, ,, "Oxygen absorbed" *at once* - -	93	,,
,, ,, ,, ,, *in 4 hours* -	93	,,
,, ,, Suspended Solids - - nearly	100	,,

So far, therefore, as the production of a good chemical effluent from a very strong sewage is concerned, the triple treatment at Hampton has been thoroughly successful.

Of the three remaining tertiary effluents examined chemically, No. 493, a sample of first runnings, contained practically no suspended matter, but was otherwise very indifferent, failing to withstand the incubator test and using up nearly two parts of nitric nitrogen in the process. The other two samples, Nos. 3148 and 542, both of which were drainings, were, as might have been expected, good—No. 3148 very good.

Attention may be called here to some comparative figures on rate of absorption of dissolved oxygen by No. 673, when diluted with tap-water in the proportion of two volumes of water to one of effluent. This sample, while slightly opalescent, contained only a trace of sediment. The respective amounts of oxygen taken up in one to five days (in parts per 100,000, by weight) were :—

24 hours.	48 hours.	72 hours.	120 hours.
0·38.	0·99.	1·34.	2·11.

This absorption, by a fairly well purified effluent, thus appears to vary almost directly with the time.

Bacteriological Results.—The bacteriological results are set forth in the accompanying table. The results varied greatly, but there can be no doubt that many of the samples showed a remarkable degree of percentage purification. Thus, several of the samples yielded a negative result with ·0001 c.c. (less than 10,000 per c.c.) with the B. coli test and presumptive tests for B. coli. As regards the B. enteritidis sporogenes test, nearly

* The three first at laboratory temperature.

all the samples contained less than 100 spores of this anærobe per c.c. Excluding the worst samples, the results showed that tertiary beds composed of fine material can eliminate intestinal microbes to a striking extent. Samples 3093A, 3093B, 3093C and 3093D, of sewage, primary bed effluent, secondary bed effluent and tertiary bed effluent, respectively, were comparative, and the number of microbes per c.c. in these samples was as follows:—7,000,000, 6,600,000, 1,800,000 and 460,000; the percentage degree of improvement effected at each stage of the process of treatment being 5·6 per cent., 73 per cent. and 74 per cent. The reduction of bacteria in the tertiary bed effluent as compared with the sewage was 93 per cent.

Description of the Sample.	Number of B. coli (or gas-forming coli-like microbes).	B.S. = Bile-salt glucose peptone test. N.R. = Neutral red broth test. In = Indol test. L.P.M. = Lactose peptone milk test.	B. Enteritidis sporogenes test.	Remarks.
Tertiary bed effluent, chance sample, 22/6/02		100,000 B.S. 100,000 L.P.M.		
3034. Tertiary-bed effluent, mid-flow, 16/10/02	1,000 not 10,000 (– indol) (– clot)	100 not 1,000 In. 1,000 not 10,000 N.R. 1,000 not 10,000 L.P.M. 1,000 not 10,000 B.S.	1 not 10	
3093 D. Tertiary bed effluent, 29/1/03		1,000 not 10,000 N.R. 10,000 not 100,000 B.S.	10 not 100	460,000 microbes per c.c. (gelatine at 20°C.)
493. Tertiary bed effluent, 1st runnings, 11/3/03	10,000 not 100,000 (+indol) (– clot)	10,000 not 100,000 In. 100,000 N.R. 100,000 L.P.M.	100 not 1,000	
3148. Tertiary bed effluent, last drainings, 7/5/03		10,000 not 100,000 N.R.	10 not 100	
542. Tertiary bed effluent, last runnings, 2/6/03		1,000 not 10,000 N.R.	10 not 100	
608. Tertiary bed effluent, mid-flow, 21/9/03	1,000 not 10,000 (+indol) (+clot)	1,000 not 10,000 N.R.	10 not 100	
3258. Tertiary bed effluent, chance sample, 7/10/03	10,000 not 100,000 (– indol) (+clot)	10,000 not 100,000 N.R.	10 not 100	
644. Tertiary bed effluent, 9/12/03	100 not 1,000 (– indol) (+clot)	100 not 1,000 N.R.	1 not 10	
663. Tetriary bed effluent, 1/2/04	1,000 not 10,000 (– indol) (+clot)	1,000 not 10,000	100 not 1,000	
673. Tertiary bed effluent, 12/4/04	1,000 not 10,000 (+indol) (+clot)	1,000 not 10,000	10 not 100	
697. Tertiary bed effluent, 30/5/04	100,000 (+indol) (+clot)	10,000 not 100,000 N.R. 100,000 B.S.	10 not 100	
3537. Tertiary bed effluent, 15/8/04	100,000 (+indol) (+clot)	10,000 not 100,000 N.R. 10,000 not 100,000 L.P.M. 100,000 B.S.	10 not 100	
750. Tertiary bed effluent, 10/11/04	10,000 not 100,000	100,000 N.R. 10,000 not 100,000 B.S.	10 not 100	

Amount of sewage treated upon the filters.—Taking the average flow of sewage during our observations as 180,000 gallons per day, we have arrived at the following estimate of the amount of sewage treated upon all the filters—primary, secondary and tertiary beds included.

Amount treated per square yard per day = 53·4 gallons.
Amount treated per cube yard per day = 43·0 gallons.

Effect of temperature upon the working of the beds.—Some measurements made in June, 1902, during warm weather, showed that at that time the temperature of the sewage was raised slightly by each succeeding contact in the three beds. The lowest effluent temperature registered during our observations was 7·0°C. (44·6°F.); this was in March, 1903.

SUMMARY.

The sewage is a very strong domestic water-closet sewage, surface and subsoil waters being practically excluded from the sewers.

Originally the crude sewage itself, after merely passing through a half-inch screen, was treated on the contact beds, the works having been designed to take 210,000 gallons of sewage per day. It was found, however, within a year, that the direct treatment of this strong liquor containing much suspended matter was clogging the primary beds, to a serious extent. The method of treatment was therefore modified by converting the near portion of the surface of each primary bed into a settling bay; and from thenceforward the treatment was that of a roughly settled sewage. The sludge (probably containing about 90 per cent. of water) which is removed from these bays amounts roughly to 350 tons per annum.

In about three years from June, 1899, the capacity of the primary beds, even with this modified treatment, had fallen to 25 per cent. of that of the original empty tank; and although we observed no further diminution in capacity in these beds since then, the secondary and tertiary beds have gradually suffered in the same way. The maintenance of the primary beds for the past two and a half years at about 25 per cent. of the original empty tank capacity has been achieved partly at the cost of the secondary and tertiary beds, and partly by the expenditure of a very considerable amount of labour upon them (something like the time of three men). As the primary beds treated unsettled crude sewage for about twelve months, we are unable to say definitely what their "life" would have been if they had been filled with roughly settled sewage from the beginning.

The result of treating crude sewage for twelve months and partially settled sewage for four years has thus been to clog the primary beds to such an extent that their continued use is only possible at much expenditure for labour. Moreover, as has been already indicated, the effect of continuing to work the primary beds, after they were really unfit, has been to seriously injure the secondary beds. No. 2 secondary bed, on which our measurements of capacity were made, became unworkable after four years' use; it had then to be dug out and the material washed. The tertiary beds have also become difficult to work after five years' service, but we think that loosening of the material by turning it over will probably be sufficient to re-vivify them; the material of which those beds are composed is extremely fine and tends to consolidate naturally.

The fact that it was found necessary, after only a year's working, to revert to a preliminary process of partial settlement is sufficient to show that the treatment of the strong crude sewage on so relatively small an area of contact beds was impracticable, notwithstanding good management. On the other hand there is no doubt that, with this triple treatment of strong sewage, the risk of nuisance has been reduced to a minimum, and the final effluent has been thoroughly satisfactory from a chemical point of view.

The few primary effluents examined showed a good purification when compared with the original sewage. The secondary effluents, judged from the standpoint of final effluents, were not of high quality, and they varied considerably in composition. Two contacts of the strong crude sewage at Hampton, therefore, were barely sufficient to produce a satisfactory effluent, *per se.* The tertiary effluents, however, were all effluents of good or very good quality, chemically speaking.

Bacteriologically, the most striking feature was the remarkable *percentage* improvement in the number of excremental microbes effected by a tertiary treatment in beds of fine material. The effluents from the primary and even the secondary beds were often unsatisfactory, a result in part due to the short contact given on the primary beds and to the fact of the secondary beds being sometimes used as streaming filters.

The final effluent from the filter beds is carried by means of an underground pipe to the River Thames at Hampton Court. The volume of water in the river there is too large to permit of any useful stream observations.

Although at Hampton, the treatment of crude sewage upon contact beds has proved impracticable on the score of cost, we might point out that this need not necessarily apply in every case. The advantage of this method, in keeping down smell, might in particular cases overbalance the main disadvantage of clogging the beds. The method might possibly also be found to be economical where only very small volumes of sewage had to be treated, and where the renewal of the material of a small bed could be carried out easily. For the comparatively large volume of the strong sewage at Hampton, arriving as it does at the works in a more or less septic condition, some form of covered tank treatment is obviously desirable.

In conclusion, we should like to express our thanks to Mr. Sydney H. Chambers Surveyor to the Urban District Council, and also to Mr. T. Hughes, Manager of the Sewage Works, for much help in connection with our work at Hampton.

HARTLEY WINTNEY SEWAGE WORKS.

(HARTLEY WINTNEY RURAL DISTRICT COUNCIL.)

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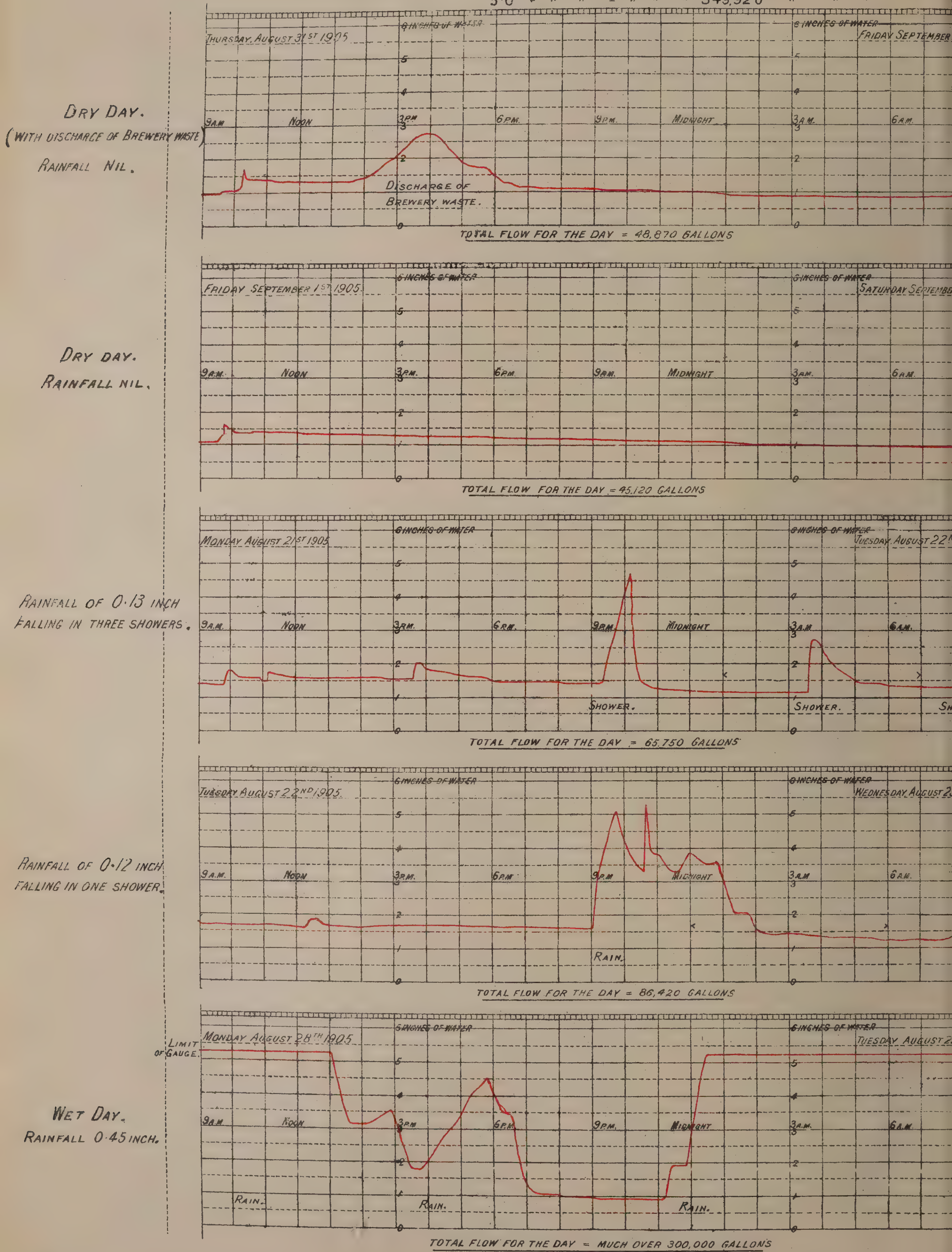
1. Situation of works - - - - - -	About 1 mile from the centre of the village.
2. Method of treatment - - - - -	Closed septic tank followed by single contact beds and land treatment (Exeter Septic Tank Company, Limited).
3. Population draining to works during observations	1,600
4. Water supply and whence obtained - - -	Private wells and Water Company; total supply, 30,000 to 35,000 gallons per day.
5. Number of W.C.'s - - - - - -	400
6. Sewerage system - - - - - -	Partially separate.
7. Average dry weather flow of sewage in gallons per 24 hours - - - - - - -	50,000
8. Gallons of sewage per head per day -	31·2
9. Character of the sewage - - - - -	Domestic, with a considerable proportion of brewery waste.
10. Period of observations - - - - -	March, 1903, to October, 1905.
11. Age of contact beds - - - - -	2½ years.
12. Amount of storm water treated on the filters	Not much more than the dry weather flow is treated on the filters.
13. Total capacity of tanks in gallons. - - -	66,000
14. Total area of contact beds in yards super	509·2
15. Total cubic content of contact beds in yards cube - - - - - - - -	679
16. Nature of filtering material - - - -	Furnace clinker from local gas works.
17. Gallons of septic liquor treated per yard super per 24 hours, based on dry weather flow (all contact beds included) - - - - -	98
18. Gallons of septic liquor treated per yard cube per 24 hours, based on dry weather flow (all contact beds included) - - - - -	73·5
19. The final effluent is discharged into -	The river Hart, which joins the river Blackwater, and finally flows into the Thames at Shiplake as the River Loddon.

Diagram L.

Diagrams showing flow of Sewage at Hartley Wintney

as falling over a Weir 9" wide.

Note:- Over a Weir 9" wide	0·75 of an inch = a rate of	20,450 gallons per 24 hours.
	1·0 " " " = " " "	31,390 " " " "
	2·0 " " " = " " "	88,850 " " " "
	3·0 " " " = " " "	162,720 " " " "
	4·0 " " " = " " "	252,000 " " " "
	5·0 " " " = " " "	349,920 " " " "



Weller & Graham. Ltd Litho. Lon

FLOW OF SEWAGE.

The flow of sewage at Hartley Wintney has been gauged on two occasions: once over a period of a week in December, 1903 (an abnormally wet year), and once over a period of 3 weeks in August and September, 1905. In the first of these periods the flow was greatly affected by wet weather throughout; but in the second, although the whole period was not dry, some good records of the dry weather flow were obtained. From these the dry weather flow has been estimated at about 50,000 gallons per 24 hours.

Except during the later part of the week, when the brewery waste is discharged into the sewers, the flow is of an even character and, as a rule, varies only from a day flow at the rate of about 75,000 gallons per 24 hours, which continues from about 9 a.m. to 5 p.m., to a night flow of rather under the rate of 40,000 gallons per 24 hours. This high rate of flow at night is no doubt due to the great length of the outfall sewer and to the large proportion of subsoil water which is mixed with the sewage.

The lowest night flow recorded was at the rate of 31,000 gallons per 24 hours.

During wet weather the variations of flow are large and rapid. On one occasion, as a result of a very heavy shower, a rise of flow in the proportion of about 5 to 1 within 10 minutes was recorded; and on several other occasions the recorder registered increases of flow in the proportion of 8 to 1 within an hour.

Subsoil Water.—From the fact that the night flow in perfectly dry weather accounts for at least half the total flow, and also because the flow of sewage remains largely swollen for some days after rain-fall has ceased, it is evident that a large quantity of subsoil water gains access to the Hartley Wintney sewers.

On Diagram L are given some illustrations of the sewage flow at Hartley Wintney.

Grit Chambers.—The main outfall sewer discharges into 2 grit chambers, each 5′ long by 2′ 6″ wide and 3′ deep. Here the heavier suspended matter in the sewage settles. It is removed about once a month and given away to farmers.

Crude Sewage.—Eleven samples in all were examined chemically, *viz.*, seven sets of hourly samples, two ordinary chance samples, one sample of weak night sewage and one of storm overflow liquor. The first series of hourly samples, Nos. 648, 651 and 654, were drawn at the beginning of January, 1904, and extended over the usual three days, Monday to Thursday. The rainfall on the first of these days amounted to 0·29″, but no rain fell on the second and third; the ground was, however, thoroughly saturated at the time, and there was a large infiltration of subsoil water into the sewers. This series may therefore be taken as representing the more dilute winter sewage. The sample of weak night sewage drawn at this time, No. 657, was taken on Thursday, January 7th, 1904, at 4.30 a.m.

The following figures were obtained:—

Parts per 100,000.		Average.	Number of Estimations	No. 567. Weak Night Sewage.
Ammoniacal Nitrogen	(2·01 to 3·11)	2·43	(3)	0·43
Albuminoid Nitrogen	(0·61 to 0·77)	0·68	(3)	0·16
Total Organic Nitrogen	(1·25 to 2·14)	1·71	(3)	—
Oxidized Nitrogen	(0·23 to 1·20)	0·64	(3)	1·46 ap.
Total Nitrogen	(4·38 to 5·11)	4·78	(3)	2·31
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(2·17 to 2·63)	2·43	(3)	0·43
,, ,, ,, *in 4 hours*	(11·04 to 20·90)	14·61	(3)	1·17
Chlorine	(6·68 to 10·62)	8·63	(3)	6·36
Suspended Solids	(11·0 to 29·1)	20·10	(3)	2·10
Solids by Centrifuge (vols.)	(64·0 to 178·0)	118·0	(3)	47·0
Ratio of Solids in Suspension to Centrifuge Solids	(1 : 5·5 to 1 : 6·1)	1 : 5·8	(3)	1 : 22·4
Incubator Test (Scudder)				+
Incubator Test (by smell)				+

The above three sets of hourly sewage samples of Series 1 were on the whole uniform as regards ammonia and total nitrogen, but the figures for "oxygen absorbed" from

permanganate and for suspended solids varied greatly ; these solids were finely divided. No. 648, the sample drawn on Monday–Tuesday, was noted as containing brewery waste, and both it and No. 651 had a somewhat sour smell when analysed. Probably all three samples had some brewery waste in them, for the solids of No. 654 (amounting to only 11 parts per 100,000) were examined microscopically and found to contain some fibre or husk, together with yeast cells. All three samples contained oxidized nitrogen, No. 651 as much as 1·2 parts. The sample of weak night sewage, No. 657, had even more than this,—about 1·5 parts, and it withstood incubation. There can thus be no question as to the presence of large quantities of subsoil water in the sewage when the ground is wet.

The wet weather winter sewage may be looked upon as of about average strength excepting in the matter of suspended solids, which are below average, and in the "oxygen absorbed" figure, which is distinctly high. Although on the one hand it contains very considerable quantities of nitrate, there is on the other much brewery refuse present, and it is therefore, no doubt, a somewhat difficult sewage to treat (Cf. notes on the Second Series of Hourly Samples, below).

The drawing of another series of hourly samples of sewage was begun on Monday August 21st, 1905, but rain put a stop to this after the first day's sample, No. 817, had been taken ; during these 24 hours 0·13″ of rain fell. Sampling was renewed on Monday, September 5th, 1905, and continued for the usual three days (Samples No. 818, 819 and 820), the rainfall for these days amounting to 0·01″, 0·05, and 0·40″ respectively. Excepting that the last sample, No, 820, was weaker than the others as regards ammoniacal and total nitrogen, and that the second one, No. 818, contained much the least suspended solids, the four sets of samples did not differ very materially. They may therefore be grouped together as Series 2. During the sampling of this second series, the conditions of the first series were exactly reversed ; the ground was quite dry, in consequence of a dry season, and although a good deal of rain fell upon the first and fourth days of sampling, the dryness of the ground caused its effect upon the flow of sewage to be but temporary.

The following results were obtained on analysis :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen- - - - - - -	(5·55 to 8·53)	7·47	(4)
Albuminoid Nitrogen - - - - - -	(1·28 to 2·34)	1·79	(4)
Total Organic Nitrogen - - - - - -	(2·28 to 4·41)	3·28	(4)
Total Nitrogen - - - - - - - -	(8·61 to 11·93)	10·75	(4)
"Oxygen absorbed" at 27°C. (80°F.) *at once* - - -	(3·82 to 6·14)	5·14	(4)
" " " *in 4 hours* - -	(15·07 to 21·48)	18·64	(4)
Chlorine - - - - - - - - -	(10·00 to 14·94)	13·20	(4)
Suspended solids - - - - - - -	(19·0 to 42·0)	32·7	(4)
Solids by centrifuge (vols.) - - - - -	(260·0 in No. 820)		

This second series of hourly sewage samples was thus much stronger than the first, more especially as regards nitrogenous matter. To take a few comparative average figures :—

	Series 1.	Series 2.
Total Nitrogen - - - - - - - - - -	4·78	10·75
Organic Nitrogen - - - - - - - - - -	1·71	3·28
"Oxygen absorbed" *in 4 hours* - - - - - - -	14·61	18·64
Solids in suspension - - - - - - - - -	20·10	32·70

All four samples of Series 2 had a strong smell when analysed, and showed much sulphuretted hydrogen. The suspended solids were, for an unscreened sewage, in a fine state of division. The dry-weather sewage is thus a very strong one and, though its suspended solids are not excessive, these are partly derived from brewery waste.

The figures of analysis of the three chance samples of sewage examined are interesting, and may therefore be given here also :—

Parts per 100,000.	No. 3,116.	No. 3,172.	No. 643. Storm overflow Liquor.
Ammoniacal Nitrogen	5·49	—	—
Albuminoid Nitrogen	1·21	—	—
Total Nitrogen	—	—	6·07
"Oxygen absorbed" at 27°C. (80°F.) *at once*	5·91	2·83	2·15
" " *in 4 hours*	26·81	10·62	12·96
Solids in suspension	42·60	—	141·60
Solids by centrifuge (vols.)	216·0	153·0	—
"Cellulose"	5·44	—	—

No. 3116 was drawn at mid-day in March, 1903, in dry weather following wet. No brewery waste was coming to the works at the time, but the sample had a strong smell of paraffin. No. 3172, drawn in dry weather in June, 1903, at 10.45 a.m., was also free from brewery waste. The storm water sample, No. 643, was taken on Monday, December 7th, 1903, at 1 p.m., after the overflow had been working for 30 minutes. It contained as much as 142 parts of suspended solids, of which 56 parts were organic; though it had not much smell when analysed, it became of course very putrid upon incubation. The desirability of settling the solids from such a storm overflow liquor is obvious.

Bacteriological Notes.—Seven samples were examined bacteriologically. All the samples, with the exception of No. 657, yielded positive results with the B. coli test and presumptive tests for B. coli with ·00001 c.c. (100,000 per c.c.). No. 657, a sample of weak night sewage, yielded negative results with the foregoing tests with ·0001 c.c. (less than 10,000 per c.c.) and a negative result with the B. enteritidis sporogenes test with ·1 c.c. (less than 10 per c.c.). Excluding No. 657, four of the samples contained 100 and two of the samples 1,000 spores of B. entéritidis sporogenes per c.c.

Description of the Samples.	Number of B. Coli (or gas-forming coli-like microbes).	B.S. = Bile-salt glucose peptone test. N.R. = Neutral red broth test. IN. = Indol test. L.P.M. = Lactose peptone milk test.	B. Enteritidis sporogenes test.	Remarks.
3116. Hartley Wintney crude sewage, 10/3/03.	—	100,000 N.R,	100 not 1,000	
3172. Hartley Wintney crude sewage, 25/6/03.	—	100,000 N.R.	100 not 1,000	
657. Hartley Wintney crude sewage, 7/1/04. (weak sewage.)	1,000 not 10,000 (+ Indol) (+ Clot)	1,000 not 10,000 N.R.	Negative $\frac{1}{10}$ c.c.	
817. Hartley Wintney crude sewage, 22/8/05.	—	100,000 B.S. 100,000 N.R.	100 not 1,000	
818. Hartley Wintney crude sewage, 5/9/05.	—	100,000 B.S. 100,000 N.R.	1000, not 10,000	
819. Hartley Wintney crude sewage, 6/9/05.	—	100,000 B.S. 100,000 N.R.	1000, not 10 000	
820. Hartley Wintney crude sewage, 7/9/05.	—	100,000 B.S. 100,000 N R.	100 not 1,000	

SEPTIC BEDS.

Number - - - - - -	2.
Size of each - - - -	70′ by 10′
Depth of water - - -	High water, 7′ 9′ Low water, 7′ (*Note.*—An automatic cut-off valve, situated in the outlet channel from the tank, regulates the outflow of septic liquor, and in consequence of this the level of the water in the tanks varies from time to time.)
Capacity of each tank - -	Mean water level, 33,000 gallons.
Total capacity - - - -	Mean water level, 66,000 gallons.

Construction.—Both septic tanks are constructed of concrete throughout, and are covered with arched concrete roofs. They contain no submerged walls.

The sewage from the grit chambers, after having been led to the tanks by means of two channels, is delivered into each tank below the water level through two pipes, while at the outlet end it issues, again below the water level, through slotted pipes extending the whole way across the outlet end of the tank.

Flow Through.—With a dry weather flow of 50,000 gallons per day, the flow through the tanks, assuming it to be a continuous one, would be once in 31·7 hours at the rate of ·44 inch per minute.

Working.—The tanks are used in parallel. In consequence of there being two groups of filters, and owing to the fact that when one filter in each group is full the automatic flow of tank liquor has to stop till one or other of the filters begins to discharge, the level of water in the septic tank fluctuates. If the flow of sewage is small, this arrangement gives a reserve capacity for the irregularities in the flow and for the first rush of storm water. If the flow of sewage is greater than the flow of tank liquor to the two filters which are filling, or sufficient, when two filters are full, to take up all the reserve storage in the tank, the whole of the sewage then flows over the storm-overflow.

Sludging.—The septic tanks were brought into use in August, 1900, and from that time worked continuously up to the early part of 1905 without the removal of any sludge whatever. Towards the end of 1904, however, owing to the large quantity of suspended matter issuing in the tank liquor, the filters became badly choked; and in the spring of 1905 an attempt was therefore made to obtain a better tank liquor as regards suspended matter.

At the outlet end of each tank a slotted pipe, laid at the bottom of a grip in the concrete, connects to a sludge well at the side of the tank. On opening the controlling valves of these, the head of water in the tank forces some of the sludge lying at the bottom into the sludge well. From there it can be lifted to the land by means of a chain pump.

By this means a fair quantity of sludge was removed on the occasion referred to, and from that time the method of removing some sludge in this way about once a month has been followed.

Although a considerable amount of sludge had been removed in this way at the end of our observations in August, 1905, its proportion to the accumulated sludge still lying towards the inlet end of the tank appeared to be small, and it seems evident that, if the greater portion of the sludge is to be removed, some other plan will have to be adopted.

Some smell is produced from the sludge during the operation referred to, but it is not great, and as the works are some distance away from any houses, no nuisance can be said to arise from it.

Septic Tank Liquor.—Three sets of hourly samples and three chance samples of septic tank liquor were examined chemically. The hourly samples, Nos. 649, 652 and 655, were drawn at the same time and under the same conditions as the first series of hourly sewage samples; hence they may be taken as representing the tank liquor from the more dilute winter sewage. At the time they were drawn the tank had been in use for nearly three and a half years.

The following figures were obtained :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - - - - - -	(2·44 to 3·51)	3·13	(3)
Albuminoid Nitrogen - - - - - - - -	(0·63 to 0·96)	0·73	(3)
Total Organic Nitrogen - - - - - - - -	(1·33 to 2·40)	1·85	(3)
Oxidized Nitrogen - - - - - - -	(0·84 in No. 655)	—	—
Total Nitrogen - - - - - - - - -	(4·77 to 5·68)	5·26	(3)
"Oxygen absorbed" at 27°C. (80°F.) *at once* - - - -	(1·95 to 2·52)	2·22	(3)
,, ,, *in 4 hours* - - - - - - -	(7·68 to 17·83)	13·16	(3)
Chlorine - - - - - - - - - -	(8·34 to 10·62)	9·44	(3)
Solids in suspension - - - - - - - -	(10·1 to 24·0)	15·10	(3)
Solids by centrifuge (vols.) - - - - - -	(52·0 to 123·0)	73·0	(3)
Ratio of solids in suspension to centrifuge solids - -	(1 : 4·4 to 1 : 5·1)	1 : 4·7	(3)

These three hourly sets of samples of septic tank liquor were fairly uniform as regards total nitrogen, but they varied greatly in their figures for "oxygen absorbed" and suspended solids. Taken all over, they apparently represent a slightly stronger liquid than the three hourly sets of sewage drawn on the same days. It will be seen that the last sample, No. 655, contained as much as 0·84 part of oxidized nitrogen; Nos. 649 and 652 do not appear to have been tested for this, and they may possibly have contained a little also, in which case the figures given for organic nitrogen would be rather too high. The suspended solids on the three days came to 11, 10 and 24 parts respectively, the last sample containing a large quantity of yeast cells.

As compared with the hourly samples of sewage, *Series* 1, these samples of septic tank liquor show very little reduction in figures, viz. :

Calculated on :—

Total Nitrogen - - - -	+ 10	per cent. reduction.
Albuminoid Nitrogen - - -	+ 7	,, ,, ,,
"Oxygen absorbed" *in 4 hours* -	10	,, ,, ,,
Solids in suspension - - -	25	,, ,, ,,

The settlement effected by the tank in January, 1904, after it had been in use for three and a half years, was thus poor, both relatively and absolutely, and the liquid sent on to the filters, though not very rich in nitrogen, contained large quantities of suspended solids and of oxidizable matter generally.

Septic Tank Liquor, Chance Samples.—No. 3117 was drawn in March, 1903, in dry weather following wet. It contained about an equal amount of nitrogen to the hourly samples, but gave much lower figures for "oxygen absorbed" (6·5) and suspended solids (9·8).

Sample No. 783, drawn in dry weather in February, 1905, gave :—

Total Nitrogen - - - - - - - - - -	9·5
"Oxygen absorbed" in 4 hours - - - - - -	13·9
Solids in suspension - - - - - - - - -	17·0

It was thus much stronger in nitrogen than the first series of hourly sewage samples, and corresponded much more nearly to the second series taken in warm dry weather.

No. 3173 may also be brought in here, though it cannot, properly speaking, be called a sample of septic tank liquor. It was drawn from the surface of a filter bed on which the tank liquor had stood 6 inches deep for $1\frac{1}{2}$ hours. No corresponding sample of untreated tank liquor was taken, but the few figures obtained for No. 3173 (viz., "oxygen

absorbed" in 4 hours, 4·8; solids by Centrifuge 12·0) show that a very material purification must have been effected, though mainly as regards suspended matter. When the bed came to be run off, this liquid would necessarily lower the general quality of the effluent.

Bacteriological Notes.—Five samples were examined bacteriologically. With one exception (No. 783) all the samples yielded positive results with the B. coli test and neutral red broth test with ·00001 c.c. (100,000 per c.c.). Four out of five samples yielded positive results with ·01 c.c. (100 per c.c.) with the B. enteritidis sporogenes test. Sample 783 yielded lower results (+·0001 c.c.—·00001 c.c.) with the B. coli, bile-salt glucose peptone, and neutral red broth tests, but higher results (+·001 c.c.; —·0001 c.c.) with the B. enteritidis sporogenes test.

Description of the Samples.	Number of B. Coli (or gas-forming coli-like microbes).	B.S. = Bile-salt glucose peptone test. N.R. = Neutral Red Broth test. In. = Indol Test. L.P.M. = Lactose peptone milk test.	B. Enteritidis sporogenes test.	Remarks.
3117. Hartley Wintney septic tank liquor, 10/3/03.	—	100,000 N.R.	100 not 1,000	
649. Hartley Wintney septic tank liquor, 4/1/04.	100,000 (– indol) (– clot)	100,000 N.R.	100 not 1,000	
652. Hartley Wintney septic tank liquor, 6/1/04.	100,000 (+ indol) (+ clot)	100,000 N.R.	100 not 1,000	
655. Hartley Wintney septic tank liquor, 7/1/04.	100,000 (+ indol) (+ clot)	100,000 N.R.	100 not 1,000	
783. Hartley Wintney septic tank liquor, 14/2/05.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 B.S. 10,000 not 100,000 N.R.	1,000 not 10,000	

FILTERS.

Number - - - - -	8.
Size of each - - - -	4 filters, 24′ by 23′ 9″. 4 filters, 24′ by 24′.
Area of each - - - -	4 filters, 63·3 square yds. each. 4 filters, 64 square yds. each.
Total area - - - - -	509·2 square yds.
Depth of material - - -	4′. (*Note.*—This has now risen to over 4′ 6″.)
Cubic content of each - -	4 filters, 84·4 cube yds. 4 filters, 85·3 cube yds.
Total cubic content - - -	679 cube yds.
Material - - - - -	Furnace clinker broken to pass a ½″ screen and freed from dust.
Construction - - - -	Brick and cement with concrete bottoms.
Distribution - - - -	Three lines of 6″ stoneware channels diminishing to 4″, laid on the top of the filtering material and fed by a main 6″ distributor.

Underdraining.—The effluent is collected at the bottom of the filter by means of 12 lines of 2″ agricultural pipes laid on the filter floor. These discharge into a stoneware main collector, from 4″ to 6″ in diameter, which connects to a cast iron discharge well containing the discharge valve.

Working.—The filters are divided into two groups of four filters each, three filters in each group constituting the working set. The filling and emptying is effected automatically, by means of the automatic gear constructed by the Septic Tank Company, Limited.

As soon as a filter is filled, a small quantity of filtered effluent flows from the discharge valve into its actuating bucket. The fall of this bucket closes the admission valve to the filter and, on rising again by syphon after a proper interval has elapsed, opens the discharge valve and releases the contents of the filter. The discharge of a full filter brings about the emptying of the actuating bucket in the next filter by syphon, and the counterweight of this then comes into play, closing its discharge valve and opening its admission valve.

The gear of each set is so arranged as to fill automatically only one filter at a time, and the flow of tank liquor to the filters is stopped during the whole time that a filter remains full. The arrangement confines the fluctuations in the sewage flow to the tanks, and also provides for the quick filling of the filters.

The overflow pipes from all the filters are connected into a continuous ring by means of a fourway cock placed at every junction. By the manipulation of this, any filter may be cut out or brought into the working set.

The time taken in filling a bed, and the length of contact given by it have varied considerably during the life of the beds, partly because of the loss of capacity in them, and partly owing to the increase in the flow of sewage which has taken place since they were started. During the observations, however, the beds have, as a rule, filled in about 40 minutes, and have given a contact of about 2 hours. The number of fillings given to the bed per day during the observations has gradually increased. At the commencement, in March, 1903, it was 1·25 fillings for each bed per day, while at the end of 1904, it had increased to an average of about 2·5 per day; this, being practically the limit. only just enables the filters to treat the whole of the ordinary sewage flow.

Age of Beds.—The beds were first started in August, 1900.

Capacity.—The original empty tank capacity of all the filters together was 114,547 the gallons, and on the assumption, therefore, that the filter material, when first put into bed, occupied one half of the bed space, the original total water capacity was 57,273 gallons.

When the observations were commenced, it was intended to make several gaugings of the filter capacities. As they went on, however, this appeared to be almost impracticable, owing to the fact that most of the feed pipes are covered in. Nevertheless, the increase in the number of fillings and the change in appearance of the beds themselves have been so marked that it has been possible to follow the history of the beds fairly completely, without actual measurements.

At the commencement of the observations, in March, 1903, the beds were receiving on the average about 1¼ fillings per day. They appeared to be in fairly good condition at this time. From then to October, 1905, however, they gradually deteriorated in appearance, owing to the excessive quantity of suspended matter in the tank liquor, and at the end they presented a black, spongy, and very sodden appearance.

The number of fillings on a dry day had also increased to an average of about 2½, which was the maximum for the setting of the gear, so that any increase of sewage flow above the normal was diverted to the land. Their appearance and the difficulty of working them made it necessary that something should be done, and the manager therefore adopted the plan of completely turning the material, so as to loosen it as much as possible. The filters were much improved by this, and up to the end of the observations, although still working ordinarily at the maximum, they have kept in fairly good order. But even during the dry weather which prevailed during the summer of 1905 it was obvious that something further than this was required, and we understand that in the near future they are to be riddled and washed and partly renewed.

The chief cause of the clogging has undoubtedly been the excessive quantity of suspended matter which they have been called upon to treat; but it is certain also that the furnace clinker which constitutes the material has disintegrated considerably.

Amount of Septic Tank Liquor treated upon the filters.—On the basis of a dry weather flow of 50,000 gallons per day, the amount of septic liquor treated by the filters is as follows:—

Per square yard per 24 hours - - - -	98 gallons.
Per cube yard per 24 hours - - - -	73·5 gallons.

Effluents. Hourly Samples.—In addition to seven chance samples, three sets of hourly samples of effluent, Nos. 650, 653 and 656, were drawn in the beginning of January, 1904, at the same time as the first series of hourly sets of crude sewage and the hourly sets of tank liquor; like these, therefore, they may be taken as typical of the more dilute winter sewage. Each set was made up of equal quantities from all the contact bed discharges for the day (fifteen in each case), taken at midflow.

The following figures were obtained:—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(1·08 to 1·22)	1·16	(3)
Albuminoid Nitrogen	(0·25 to 0·29)	0·27	(3)
Total Organic Nitrogen	(0·38 to 0·48)	0·42	(3)
Oxidized Nitrogen	(0·85 to 1·60)	1·22	(3)
Total Nitrogen	(2·32 to 3·15)	2·83	(3)
"Oxygen absorbed" at 27°C. (80°F.) *at once*	(0·60 to 0·97)	0·80	(3)
,, ,, *in 4 hours*	(2·41 to 3·55)	3·14	(3)
Chlorine	(7·98 to 9·84)	8·87	(3)
Solids in suspension	(3·0 to 3·7)	3·30	(3)
Solids by centrifuge (vols.)	(29·0 to 35·0)	31·0	(3)
Ratio of solids in suspension to centrifuge solids	(1 : 8·1 to 1 : 10·6)	1 : 9·5	(3)
Incubator test (Scudder)		2 +	(2)
,, ,, (by smell)		1 +, 2 (?)	(3)
Smell when drawn		3 −	(3)
Smell when analysed		3 +	(3)

In appearance these hourly samples of effluent were turbid and yellowish, and they contained about 3 parts by weight of reddish brown suspended matter of a flocculent character; they were on the whole very uniform in composition. Though they all had a smell of sewage when drawn, this had changed to a clean earthy smell next morning. The incubation results were less satisfactory than usual, but perhaps two out of the three samples withstood incubation. Nearly half of the total nitrogen present was in the oxidized state, but on the other hand the effluents also contained appreciable quantities of unoxidized organic matter. For one contact they show a very large percentage reduction in figures, when compared with the hourly samples of sewage and tank liquor drawn at the same time (see below), but purification had not gone quite far enough for them to be regarded as satisfactory, if they were to be considered final effluents.

Compared with the hourly samples of sewage and of tank liquor, we get the following reductions:—

Calculated on	Sewage.	Septic Tank Liquor.
Albuminoid Nitrogen	60 per cent.	63 per cent. reduction.
Total Organic Nitrogen	75 ,,	77 ,, ,,
Total Nitrogen	41 ,,	46 ,, ,,
"Oxygen absorbed" *at once*	67 ,,	64 ,, ,,
,, ,, *in 4 hours*	79 ,,	76 ,, ,,
Solids in suspension	84 ,,	78 ,, ,,
Solids by centrifuge (vols.)	74 ,,	57 ,, ,,

Effluents. Chance Samples.—Seven chance samples of effluent, Nos. 3118, 3174, 669, 3549, 757, 784 and 610, were examined chemically. Six of the seven were drawn in the cooler months of the year, five in dry weather and two in dry weather following wet. Excepting No. 610, which was a sample of last drainings from a bed, all the samples were taken at mid-flow; the hour of drawing varied between 12.15 noon and 5.15 p.m.

The following figures were obtained :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(1·15 to 5·79)	3·20	(7)
Albuminoid Nitrogen	(0·21 to 0·75)	0·41 (1)	(6)
Total Organic Nitrogen	(0·45 to 1·22)	1·11	(3)
Oxidized Nitrogen	(0·0 to 2·67)	1·02	(7)
Total Nitrogen	(3·92 to 6·88)	5·71	(4)
"Oxygen absorbed" at 27°C. (80°F.) *at once*	(0·61 to 1·22)	0·87	(7)
" " *in 4 hours*	(2·65 to 4·86)	3·26	(6)
Dissolved Oxygen taken up in 24 hours at about 18° C.	(0·57 to 4·18)	2·36 ap.	(4)
Chlorine	(8·88 to 12·10)	10·13	(3)
Solids in suspension	(4·0 to 10·6)	7·20	(4)
Solids by centrifuge (vols.)	(14·0 to 106·0)	43·0	(7)
Ratio of solids in suspension to centrifuge solids	(1 : 5·2 to 1 : 11·9)	1 : 7·7	(4)
Incubator test (by smell)		2+, 5–	(7)
Smell when drawn		7–	(7)
Smell when analysed		2+, 5–	(7)

(1) This figure is possibly a little too high.

In appearance these effluents were turbid and brown, but some of them were noted as filtering through paper to a fairly bright liquid of brownish tinge, and this no doubt applied to all. They contained more suspended solids than the hourly samples of effluent. All of them had a sewage or tank smell when drawn, and five of the seven when analysed, and only five out of the seven withstood incubation. The amount of dissolved oxygen taken up by four of the effluents in 24 hours—even allowing for the fact of those four being under the general average in quality—was very large, viz., 2·4 parts approximately. Those effluents were thus not satisfactory if they were to be considered as final effluents, and that they required settlement is obvious. Taken all over, these were effluents from the treatment of stronger tank liquors than the hourly samples of effluent.

It is impossible to draw any strict conclusion as to reduction in figures, seeing that only two samples of tank liquor were drawn to correspond with two of the seven chance samples of effluent; but perhaps the best approximate idea will be gained by contrasting those seven with series 2 of the hourly samples of sewage (the dry weather series). In that case we get :—

Calculated on Hourly Samples of Sewage: Series 2.	———
Albuminoid Nitrogen	77 per cent. reduction.
"Oxygen absorbed" *at once*	83 " "
" " *in 4 hours*	83 " "
Solids in suspension	78 " "

Three of the foregoing chance samples of effluent, Nos. 3549, 757 and 784, were examined both before and after filtration through paper or settlement. No. 3549 was the worst sample obtained from Hartley Wintney, having been drawn from a bed in very clogged condition, and the others were also very poor samples. Still the effect

produced by the removal of the solids from these effluents was very marked. The respective comparative figures may be given here :—

Parts per 100,000.	No. 3,549.		No. 757.		No. 784.		
	Original.	Filtered.	Original.	Filtered.	Original.	Settled.	Filtered.
Ammoniacal Nitrogen - -	5·65	5·95 (1)	5·79		3·04	3·31	3·32
Albuminoid Nitrogen - -	0·75	0·46			0·31	0·34	0·31
Total Organic Nitrogen -	1·22				1·66		0·46
Nitric and Nitrous Nitrogen -	0·0	0·0	0·27 ap.	0·27 ap.	1·01	1·01	1·01
"Oxygen absorbed" *at once* -	1·22	0·65	0·61	0·45	0·76	0·56	0·52
" " *in 4 hours*	4·86	3·08	2·65	1·35	3·01	2·78	1·73
Dissolved Oxygen taken up in 24 hours.	4·18	2·07	0·57	* 0·39	2·28 in 48 hours.	0·52	0·45
Incubator test (by smell) -	–	–	–	+	–	+	+
Solids in suspension - -	10·6		8·9		5·3		
Solids by centrifuge (vols.) -	55·0		106·0		40·0		

(1) Probably rather too high.
* After incubation for 13 days, this filtered sample had taken up over 12 parts of Oxygen.

Bacteriological Notes.—Ten samples of effluent were examined bacteriologically. As regards the B. Coli test and presumptive tests for B. Coli, the worst samples yielded positive results with ·00001 c.c. (100,000 per c.c.); the best samples positive results with ·001 c.c. (1,000 per c.c.); and about half the samples positive results with ·0001 c.c. (10,000 per c.c.). Most (7 out of 10) of the samples contained less than 100 spores of B. enteritidis sporogenes per c.c.

Description of the Samples.	Number of B. Coli (or gas-forming coli-like microbes).	B.S. = Bile-salt glucose peptone test. N.R. = Neutral red broth test. In. = Indol test. L.P.M. = Lactose peptone milk test.	B. Enteritidis sporogenes test.	Remarks.
3118. Hartley Wintney filter effluent, 10/3/03.	10,000 not 100,000 (+ indol) (+ clot)	1,000 not 10,000 B.S. 10,000 not 100,000 N.R. 100,000 In.	10 not 100	
3174. Hartley Wintney filter effluent, 25/6/03.	—	100,000 N.R.	100 not 1,000	
610. Hartley Wintney filter effluent, 28/9/03.	100,000 (+ indol) (+ clot)	100,000 N.R.	10 not 100	
650. Hartley Wintney filter effluent, 4/1/04.	1,000 not 10,000 (+ indol) (+ clot)	1,000 not 10,000 N.R.	10 not 100	
653. Hartley Wintney filter effluent, 6/1/04.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R.	10 not 100	
656. Hartley Wintney filter effluent, 7/1/04.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R.	10 not 100	
669. Hartley Wintney filter effluent, 7/3/04.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R.	10 not 100	
3549. Hartley Wintney filter effluent, 5/10/04.	100,000 (+ indol) (+ clot)	100,000 B.S. 100,000 N.R.	1,000 not 10,000	
757. Hartley Wintney filter effluent, 28/11/04.	1,000 not 10,000 (+ indol) (+ clot)	1,000 not 10,000 B.S. 1,000 not 10,000 N.R.	10 not 100	
784. Hartley Wintney filter effluent, 14/2/05.	10,000 not 100,000 (+ indol) (– clot)	10,000 not 100,000 B.S. 10,000 not 100,000 N.R	100 not 1,000	

LAND.

Owing to the fact that the land treatment did not come within the scope of our observations, we have paid little attention to it. But it may be stated that the land has an area of approximately five acres, three of which are available for the treatment of the filter effluent, while almost the whole of it is available for sewage and sludge; it consists of a stiff loam surface soil overlying gravel, and it is not under-drained.

The filter effluent is distributed by means of grips cut in the soil. being collected again and delivered at one outlet.

Some osiers are grown on the lower part of the land, but otherwise it is not cropped.

SUMMARY.

The dry-weather sewage is very strong, and, although its suspended solids are not excessive in quantity, these are partly derived from brewery waste, and are therefore probably of a somewhat refractory nature. There is a large infiltration of subsoil water into the sewers, even in dry weather.

With regard to the settlement of solids effected by the septic tanks, our observations have of necessity been limited; but, so far as they have gone, and judging from the general appearance of the tank liquor, the settlement has been poor. This may be ascribed to the fact that no sludge was removed from the tanks for a period of 3½ years from their installation, and also to the solids of the brewery waste being largely of a light and fermentable character. The only method at present of removing sludge from the tanks is by means of a 6-inch slotted pipe, laid in a grip in the concrete at the bottom of each tank, close to the outlet end; this delivers to a sludge well, from which the sludge is lifted by means of a chain pump. Although a considerable quantity of sludge is now removed in this way, we think that the heavier matter over the whole floor of the tank can be but little affected. It would probably have been advisable—in the interests both of the filters and of the septic tanks—to have had larger grit chambers than there are at present, and, instead of one cleansing pipe only, to have had several extending to the inlet ends of the septic tanks, so as to allow of a fair proportion of the accumulated sludge being removed periodically. Since only a comparatively small quantity of sludge has, so far, been taken from the tanks at intervals from the spring of this year (1905), its disposal has presented no difficulty.

After 5 years' work, at a rate varying from one filling per day at the commencement to 2½ fillings per day in September, 1905, the beds had got into such a condition as to necessitate either riddling, washing, or renewal of the material, and this, notwithstanding the fact that the whole of the clinker in the filters had been turned over in the spring and summer of 1905.

The tank liquor is organically a strong one, and since it has also up to now contained large quantities of suspended matter, the comparatively short life of the filter beds is not surprising.

No gaugings of filter capacity have been made owing to the difficulties which stood in the way.

The automatic gear for filling and emptying the filter beds works fairly well, but requires a considerable amount of attention; owing to the occasional clogging of the syphons it cannot safely be left to itself for any great length of time. If at any moment a syphon does choke, the sewage is backed up and then overflows on to the land. Probably the gear would be much less liable to block if the sludge were emptied from the tanks more frequently, leaving the tank liquor freer from matters in suspension.

The automatic gear effects a considerable saving in labour; it may be said to save the whole time of a night man and a large part of the time of a day man. Its chief disadvantage, apart from the question of having additional filters for the treatment of storm water, lies in the fact that, owing to the period of contact being virtually constant, the total number of fillings is restricted (at its present setting 20 per day) over the whole of the 8 beds, *i.e.*, 2½ fillings for each bed per day.

For one contact of a strong septic tank liquor, the filter effluent showed a very large percentage reduction in the figures of impurity, but it would not be considered as sufficiently purified if looked upon as a final effluent. The filter effluent is finally purified on land.

During sludging operations there is considerable smell, and occasionally some smell is also apparent from the ordinary working of the process. The sewage works being, however, well removed from all dwellings and high roads, no public nuisance may be said to arise from them.

In conclusion, we would like to express our thanks to Mr. L. L. Warren, the Works Superintendent, for assistance given us throughout our observations.

HENDON SEWAGE WORKS.

(Hendon Urban District Council.)

1. Situation of works - - - -	About one mile from centres of population, some large houses being within half a mile.
2. Method of treatment - - -	Chemical precipitation and filtration through percolating filters, followed by either (1) contact beds or (2) secondary percolating filters. At night the effluent from the high level percolating filters is passed on to a plot of prepared land.
3. Population draining to works during observations - - - -	23,500. (estimated average).
4. Water supply in gallons per head and whence obtained	About 39 gallons. From the West Middlesex, Colne Valley, and New River Companies.
5. Number of w.c.'s - - - -	About 7,000
6. Sewerage system - - - -	90 per cent. of built area on the partially separate system, the remainder on the combined system.
7. Average dry weather flow of sewage in gallons per 24 hours - -	950,000.
8. Gallons of sewage per head per 24 hours	40·4.
9. Character of the sewage* - -	(1) High level sewage. A laundry sewage of rather under average strength. (2) Low level sewage. A strong domestic sewage.
10. Period of observations - - -	October, 1902, to September, 1905.
11. Age of (a) contact beds (b) percolating filters	(a) Constructed in 1898, 1899, and 1900. (b) First used in 1887; Nos. 1, 4, and 6 reconstructed in 1902 and 1903.
12. Amount of storm water treated during observations	Not more than six times the dry weather flow is treated in the tanks. Three times the dry weather flow is treated on the filters.
13. Total capacity of settling tanks in gallons - - - - -	(1) High Level, 480,000; Low Level, 210,000.
14. Total area of (a) high level percolating filters (b) contact beds in yards super	(a) 16,000. (b) 2,400.
15. Cubic content of (a) high level percolating filters (b) contact beds in yards cube.	(a) 10,000. (b) 4,000.
16. Nature of filtering material:	
(1) Contact beds - - -	Coke breeze, burnt ballast, and broken bricks.
(2) Percolating filters - -	Burnt ballast, and burnt ballast and soil
17. Gallons of precipitation liquor treated per yard super (based on the dry-weather flow).	37
18. Gallons of precipitation liquor treated per yard cube (based on the dry-weather flow).	57
19. The final effluent is discharged into -	The river Brent.

* The district is, for the most part, a residential one, but it contains some manufactories, and also a very large number of laundries. Except for a mineral water manufactory which discharges its wash water into the sewers, the manufactories are not of a kind to affect the sewage; but the numerous laundries all send their waste waters into the system.

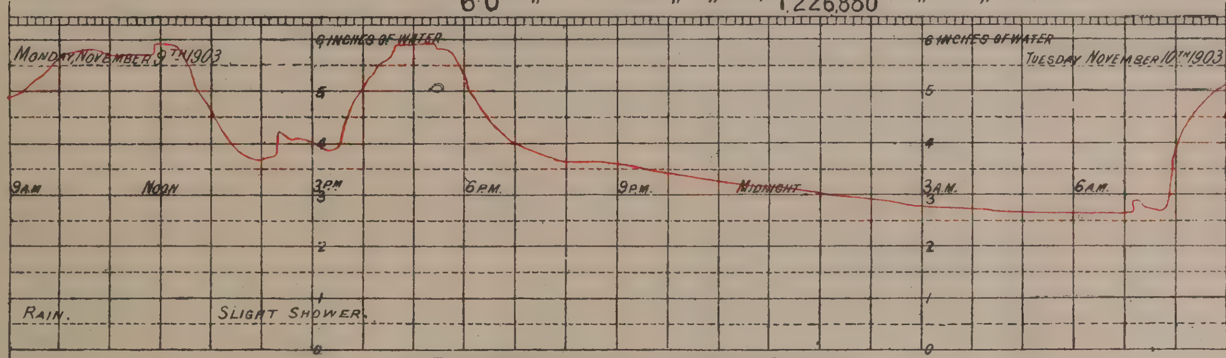
Diagram M!

Diagrams showing High Level flow of Sewage at Hendon

as falling over a Weir 24" wide.

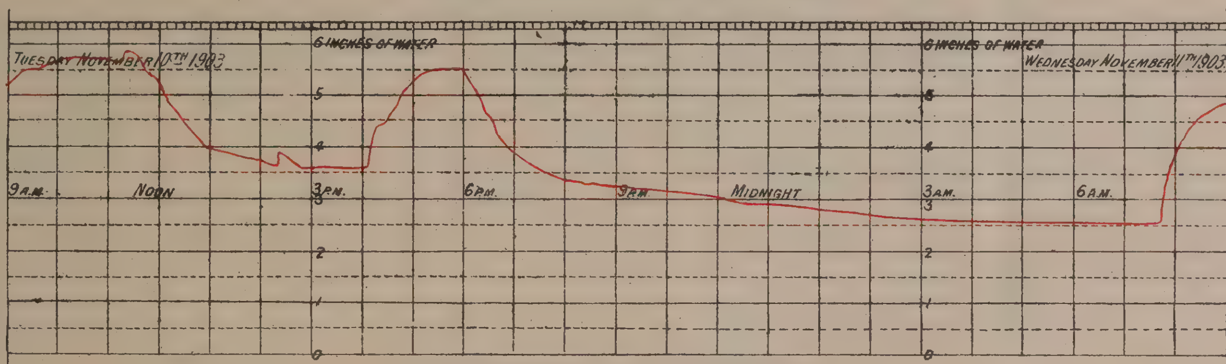
Note:- Over a Weir 24" wide			
2·5 inches	=	a rate of 329,760	gallons per 24 hours.
3·0 "	=	" " " 436,320	" " " "
4·0 "	=	" " " 671,040	" " " "
5·0 "	=	" " " 933,120	" " " "
6·0 "	=	" " " 1,226,880	" " " "

ALL 0·9 INCH.



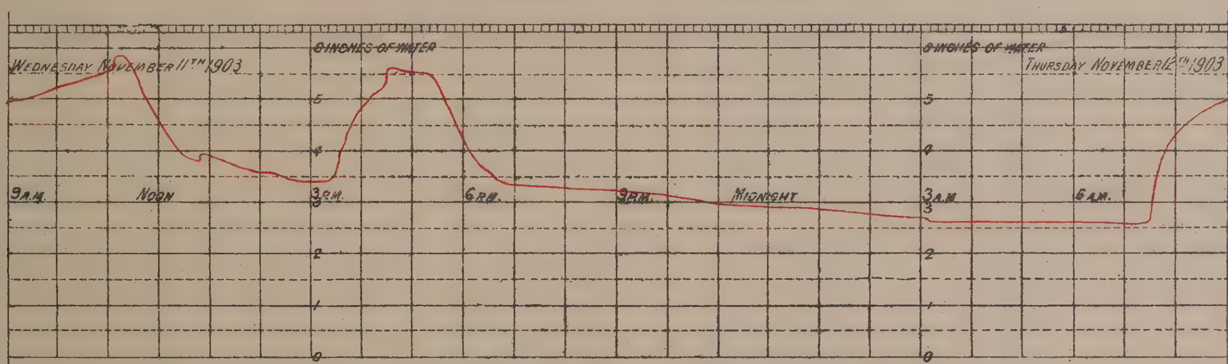
TOTAL FLOW FOR THE DAY = 790.800 GALLONS

RY DAY.
FALL NIL.
ATHER WET.)



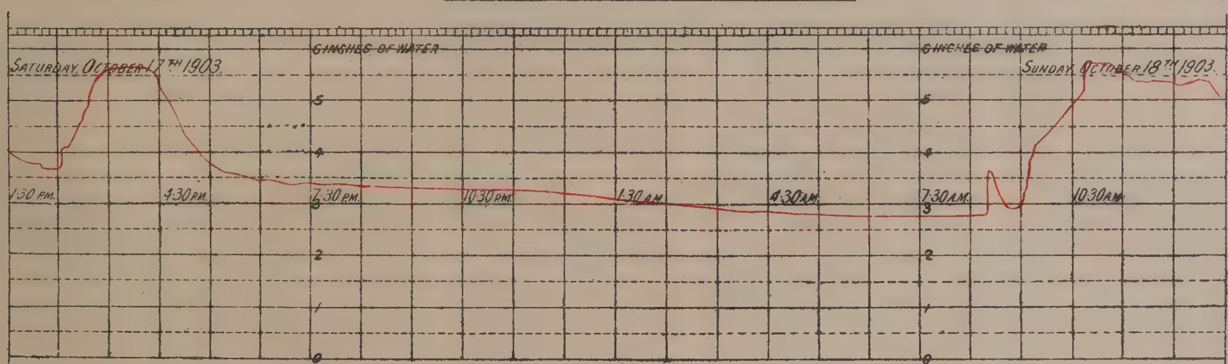
TOTAL FLOW FOR THE DAY = 711,800 GALLONS

DAY.
0·01 INCH.
ATHER WET.)



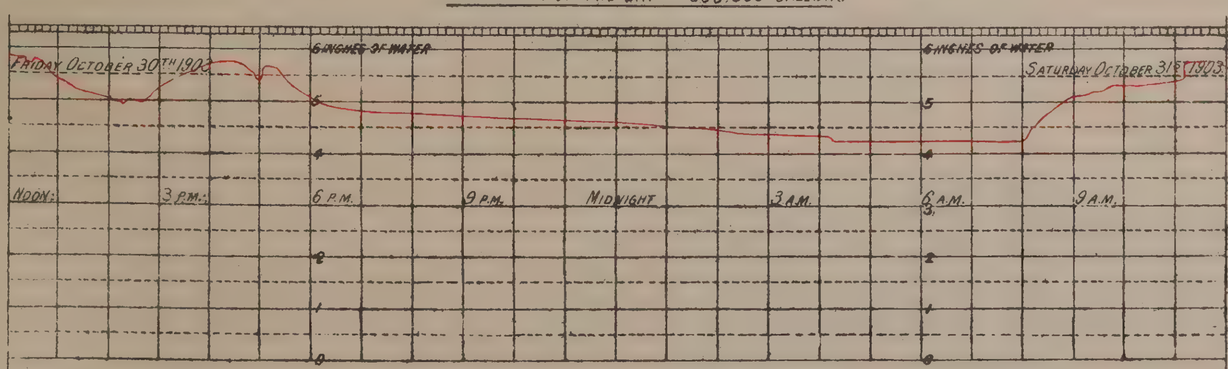
TOTAL FLOW FOR THE DAY = 676,600 GALLONS

0·03 INCH.



TOTAL FLOW FOR THE DAY = 699.800 GALLONS

DAY.
WEEK OF
T WEATHER.
L NIL.



TOTAL FLOW FOR THE DAY = 890,240 GALLONS

Note:- The heavy fluctuations of flow shewn in the above Charts are due to the pumping of part of the sewage.

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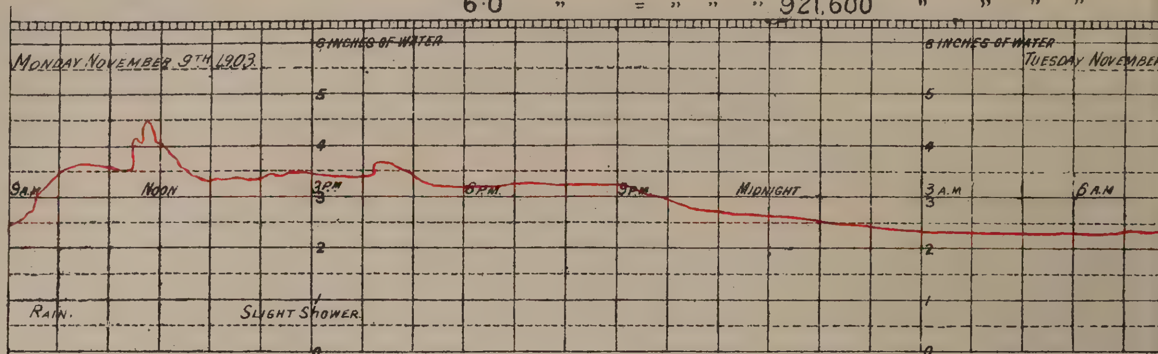
Diagram Nº 2

Diagrams showing Low Level flow of Sewage at Hendon as falling over a Weir 18" wide.

Note:- Over a Weir 18" wide

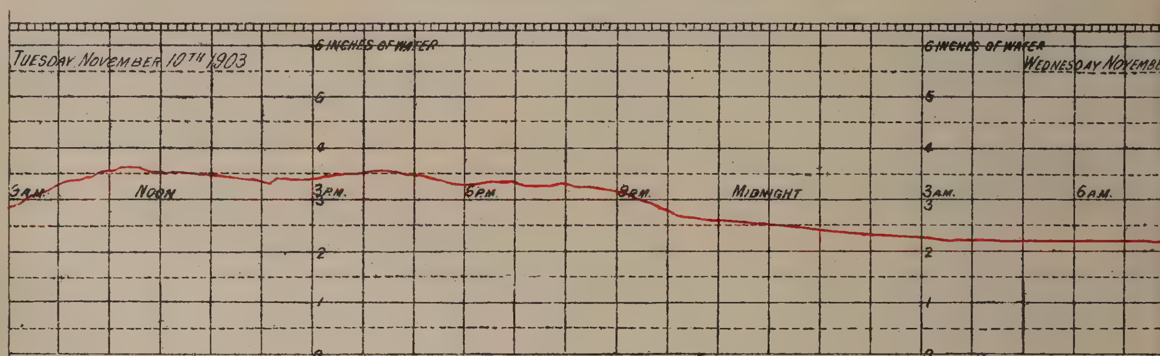
2·25 inches	=	a rate of 211,680	gallons per 24 hours.
3·0 "	=	" " " 325,440	" " " "
4·0 "	=	" " " 502,560	" " " "
5·0 "	=	" " " 698,400	" " " "
6·0 "	=	" " " 921,600	" " " "

Rainfall 0·09 inch.



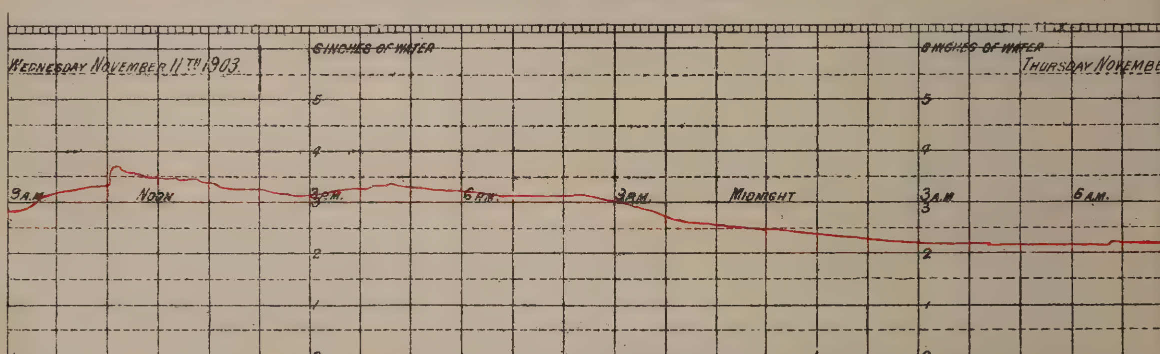
Total flow for the day = 369.800 gallons

Dry day.
Rainfall nil
(Ground rather wet).



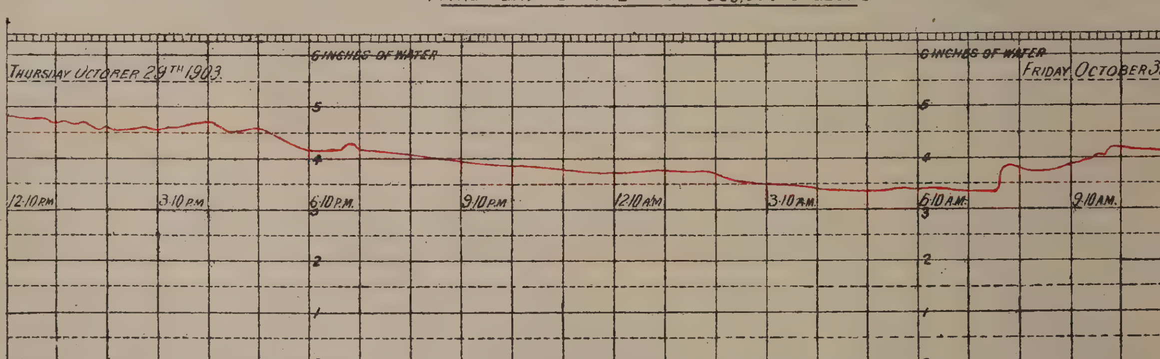
Total flow for the day = 356,000. gallons.

Dry Day.
Rainfall 0·01 inch
(Ground rather wet).



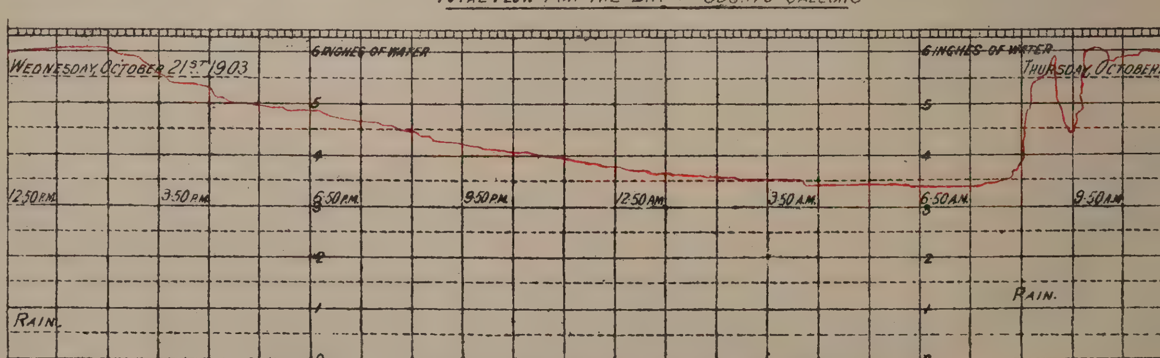
Total flow for the day = 335,000 gallons

Rainfall 0·11 inch
on wet ground.



Total flow for the day = 505.170 gallons

Rainfall 0·22 inch
on wet ground



Total flow for the day = 612.440 gallons.

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FLOW OF SEWAGE.

Owing to the inclusion of surface water from some of the streets, and also of the back roof and yard water from the whole district, the flow of sewage becomes much swollen in times of storm.

Both the main outfall sewers are capable of carrying six times the dry-weather flow, and, as they occasionally run full, this quantity is brought to the works. Any additional volume is diverted by means of six overflows on the high-level system and the same number on the low-level system.

The whole of the storm-water sewage brought to the works (*i.e.*, six times the dry-weather flow) is passed through the respective tanks, but, as a general rule, not more than three times the dry-weather flow are given double filtration, the remaining three dilutions being sent to the river after single filtration.

By means of two automatic recorders placed in the inlet channels, continuous measurements of the daily flows of both sewages were made over a period of rather more than three weeks, in October and November, 1903. During the early part of this time, the weather was wet, and as both flows are affected by rain for a considerable time after the fall has ceased, it is more than probable that the flows recorded during the dry weather which prevailed later do not represent the absolute dry weather flows. It has been possible, however, from these gaugings, together with figures which have been supplied to us by Mr. Grimley, the Engineer and Surveyor to the Council, to form the following approximate estimates of the dry weather flows during the years of observation :—

High level sewage - - - - -	650,000 gallons per 24 hours.
Low level sewage - - - - -	300,000 gallons per 24 hours.
Total flow of sewage	950,000 gallons per 24 hours.

Owing to the pumping, at three stated periods in the day, of the sewage from the lower sewer in the Hendon and Mill Hill system, the flow of high level sewage is subject to considerable variations in dry weather. At the time of the gaugings it varied from maximum rates of about $1\frac{1}{2}$ million gallons per 24 hours, occurring at 12 noon, 4 p.m., and 6 p.m., to minimum rates of rather more than 300,000 gallons per 24 hours, in the early hours of the morning.

The flow of the low level sewage during dry weather is of an even character, falling gradually from a rate of about 420,000 gallons per 24 hours, which continues steadily from 10 a.m. to 9 p.m., to a rate of about 220,000 gallons per 24 hours during the night.

In wet weather the flows of both sewages are also of an even character; but they become uneven when heavy showers fall upon ground which is already wet.

Subsoil Water.—The night flows of both sewages are heavy, and are also affected for some days after rain has ceased. We think it is to be inferred, therefore, that in addition to water leaking from taps, a quantity of ground water gains access to both systems.

On Diagrams M^1 and M^2 are given some illustrations of the sewage flows at Hendon.

High Level Sewage.—Four sets of hourly samples were examined chemically. The first set, No. 622 was drawn on Monday-Tuesday, October 19th-20th, 1903, the rainfall for the 24 hours amounting to 0·09 inch. Further rain stopped the sampling at the time and the remaining three sets, Nos. 3291, 3299 and 3307, were not taken until Monday-Thursday, November 9th-12th, 1903, the rainfall for these three days being 0·09, 0·00 and 0·01 inches respectively. The previous week was dry, but the ground was still wet from October rains. Sample No. 3291 was noted as being rather dilute, and the flow over the three days may be taken as being rather above the normal.

The first set, No. 622, was distinctly weaker than the other three,—about one-fourth weaker, and it has therefore been thought best in the first instance to average the figures from the last three samples alone, as this average may be taken to represent the quality of the dry-weather flow of the high level sewage in the month of October in a wet year. Excepting that the third sample, No. 3307, contained less suspended solids than the other two, the three sets were almost identical in composition.

It may be observed that Monday is the clothes-collecting day from the laundries at Hendon, and Tuesday, Wednesday and Thursday are washing days.

The following figures were obtained:—

	Parts per 100,000.	Average.	Number of Estimations.
Total Nitrogen	(5·19 to 5·37)	5·27	(3)
"Oxygen absorbed" at 27°C. (80°F.) *at once*	(2·84 to 3·04)	2·94	(3)
,, ,, ,, ,, *in 4 hours*	(10·23 to 11·71)	11·01	(3)
Chlorine	(6·48 to 7·32)	7·01	(3)
Solids in suspension	(18·1 to 25·1)	23·90	(3)
*Solids by centrifuge (vols.)	206·0 and 244·0)		(2)
Ratio of solids in suspension to centrifuge solids	1:8·2 and 1:8·6)		(2)
"Cellulose" (by alkali, acid and ether)	(5·64 and 5·24)		(2)
Ratio of "cellulose" to suspended solids	(1:4·5 and 1:5·4)		(2)

The following are the average figures of the four sets of hourly samples, Nos. 622, 3,291.3,299 and 3,307, taken altogether; the inclusion of the first set slightly weakens the whole average:—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(2·62)		(1)
Albuminoid Nitrogen	(0·74)		(1)
Total Organic Nitrogen	(1·47)		(1)
Total Nitrogen	(4·09 to 5·37)	4·98	(4)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(2·08 to 3·04)	2·58	(4)
,, ,, ,, ,, ,, *in 4 hours*	(8·99 to 11·71)	10·50	(4)
Chlorine	(5·30 to 7·32)	6·59	(4)
Solids in suspension	(18·1 to 28·5)	22·70	(4)
Solids by centrifuge (vols.)	(163·0 to 244·0)	204·0	(3)
Ratio of solids in suspension to centrifuge solids	(1:8·2 to 1:8·6)	1:8·5	(3)
"Cellulose" (by alkali, acid and ether)	(5·64 and 5·24)		(2)
Ratio of "cellulose" to suspended solids	(1:4·5 and 1:5·4)		(2)

Low Level Sewage.—Four sets of hourly samples of low level sewage, Nos. 624, 3,293, 3,301 and 3,309 were drawn at the same times and under exactly the same conditions as the high level samples. Here, again, the first set, No. 624, was not quite so strong as the other three, though the difference was less in this case.

* The solids in the third sample were too coarse for the centrifuge tube.

The following average of the figures of the last three sets may be taken as representing the quality of the dry-weather flow of the low level sewage in the month of October of a wet year; the three sets were almost identical in composition:—

Parts per 100,000.		Average.	Number of Estimations.
Total Nitrogen	(6·51 to 7·25)	6·54	(3)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(4·12 to 4·97)	4·42	(3)
,, ,, ,, ,, ,, *in 4 hours*	(16·88 to 18·14)	17·55	(3)
Chlorine	(7·98 to 8·58)	8·25	(3)
Solids in suspension	(32·5 to 35·0)	33·40	(3)
*Solids by centrifuge (vols.)	(366·0 and 450·0)		(2)
Ratio of solids in suspension to centrifuge solids	(1 : 11·3 and 1 : 12·9)		(2)
"Cellulose" (by alkali, acid and ether)	(6·52 and 5·84)		(2)
Ratio of "cellulose" to solids in suspension	(1 : 5·0 and 1 : 5·6)		(2)

The following are the average figures of the four sets of hourly samples, Nos. 624, 3293, 3301 and 3309, taken altogether; it will be seen that they differ but slightly from the average figures of the three last sets, which have just been given. A sample of weakest night sewage, No. 3306, drawn on Wednesday, November 11th, 1903, at 5.30 a.m., was also examined partially, and its figures of analysis are likewise appended here.

Parts per 100,000.		Average.	Number of Estimations.	No. 3306. Weakest Night Sewage.
Ammoniacal Nitrogen	(3·46)		(1)	1·24 approx.
Albuminoid Nitrogen	(0·97)		(1)	
Total Organic Nitrogen	(1·83)		(1)	
Total Nitrogen	(5·29 to 7·25)	6·54	(4)	
"Oxygen absorbed" at 27° C. *at once*	(3·12 to 4·97)	4·09	(4)	
,, ,, ,, *in 4 hours*	(15·07 to 18·14)	16·93	(4)	2·39
Chlorine	(6·42 to 8·58)	7·80	(4)	5·18
Solids in suspension	(32·5 to 35·0)	33·20	(4)	0·92
Solids by centrifuge (vols.)	(300·0 to 450·0)	372·0	(3)	13·3
Ratio of solids in suspension to centrifuge solids	(1 : 9·1 to 1 : 12·9)	1 : 11·1	(3)	1 : 14·5
"Cellulose" (by alkali, acid and ether)	(6·52 and 5·84)		(2)	
Ratio of "cellulose" to suspended solids	(1 : 5·0 and 1 : 5·6)		(2)	

It is seen from the figures of analysis that the high-level sewage is one of about average strength, but with only 24 parts of suspended solids, while the low-level sewage is of distinctly over average strength as regards oxidizable matter, as measured by the "oxygen absorbed" test, and with 33 parts of suspended solids. These solids in the hourly samples of low-level sewage were noted as being very coarse in character, the second sample containing fragments of straw, the third sample pieces of rag, and the fourth sample coarse pieces of fibre.

The respective dry-weather flows of the high-level and low-level sewages have already been given as 650,000 and 300,000 gallons per 24 hours. Taking, therefore, the figures of analysis given by the hourly samples of each of these, and averaging

* The solids in the third sample were too coarse for the centrifuge tube.

them according to their relative volumes, we get a *mixed* sewage of the following composition. This mixed sewage is what the precipitation tanks and filters at Hendon have to treat; it may be taken as a sewage of distinctly over average strength, excepting in the matter of suspended solids, which are not high.

Column I. gives the average *mixed* sewage, calculated from the six samples, Nos. 3291, 3299 and 3307 (high-level), and 3293, 3301 and 3309 (low-level); they therefore represent the whole dry-weather flow in October of a wet year. Column II. gives the average *mixed* sewage, calculated from the whole of the eight hourly sets examined :—

Mixed Sewage.	I.	II.
Total Nitrogen	5·67	5·37
"Oxygen absorbed" at 27°C. (80° F.) *at once*	3·41	3·06
,, ,, ,, ,, ,, *in 4 hours*	13·08	12·53
Chlorine	7·40	6·97
Solids in Suspension	26·90	26·0

A further ordinary chance sample of low-level crude sewage, No. 3024, drawn in dry weather, on Monday, October 13th, 1902, at 1 p.m., was roughly of about the same strength as the average samples.

No. 3306, the sample of weakest night sewage, drawn on Wednesday, November 11th, 1903, at 5.30 a.m., in dry weather, was distinctly weak, with hardly any suspended matter; unfortunately, no notes were made as to whether or not it was tested for nitrate.

Bacteriological Notes.—Only two samples of crude sewage were examined. Sample 3306 yielded positive results with the B. coli and neutral red broth tests with ·00001 c.c. (100,000 per c.c.), and contained 100 spores of B. enteritidis sporogenes per c.c. Sample 3309 yielded positive results with the B. coli and neutral red broth tests with ·0001 c.c. (10,000 per c.c.), and contained 1,000 spores of B. enteritidis sporogenes per c.c.

Description of the Sample.	Number of B. coli (or gas-forming coli-like microbes).	B.S. = Bile-salt glucose peptone test. N.R. = Neutral red broth test. In = Indol test. L.P.M. = Lactose peptone milk test.	B. enteritidis sporogenes test.	Remarks.
3306. Hendon crude sewage, 11/11/03.	100,000 (+indol) (+clot)	100,000 N.R.	100 not 1,000	
3309. Hendon crude sewage, 12/11/03.	10,000 not 100,000 (+indol) (+clot)	10,000 not 100,000 N.R.	1,000 not 10,000	

SCREENS.

Both sewages pass through vertical screens of half-inch mesh, before flowing into the precipitation tanks. There are no grit chambers at Hendon.

PRECIPITATION TANKS.

High Level Tanks.

Number	3.
Size of each	79 feet by 64 feet.
Depth of water	5 feet 6 inches.
Capacity of each	160,000 gallons.
Total Capacity	480,000 gallons.

Construction.—The high level precipitation tanks are constructed of brick and cement walls with concrete bottoms, and are fitted with sludge valves and floating arms. Each tank also contains a wall extending about two-thirds of its length along the centre of the tank.

Precipitant.—Alumino-ferric is the precipitant used for the high level sewage. It is added in the form of a solution, made by running town's water on to blocks of the precipitant placed in a box with a false bottom. The quantity added is equivalent to about **5** grains per gallon on the dry weather flow.

Flow Through.—With a dry weather flow of **650,000** gallons per **24** hours, the flow through the two tanks generally in use at one time would be once in **12** hours, at the rate of **3** inches per minute.

Working.—The plan of working the high level tanks is as follows :—Two tanks are always in use at one time. They are used in series. No. **1** tank, which is always employed as a first tank, is cleaned twice a week, on Monday and Friday. No. **2** tank, which is used alternately as a first or second tank, is cleaned once a week, on Wednesday ; and No. **3** tank, which is used as a second tank, is cleaned once a month.

Sludging.—At the end of its regular period of use, the tank to be sludged is cut out of the series and allowed to rest for a few hours. The supernatant liquor is then run off by means of a floating arm and treated upon the smaller earth filters, while the remaining sludge is allowed to gravitate to a large sludge well, from which it is pumped into trenches cut in the land.

As the sludges from both the high level and low level tanks are mixed, the method of dealing with them is described below under "Low Level Tanks."

Low Level Tanks.

Number - - - - - -	**3**.
Size of each - - - - -	**50** feet by **46** feet.
Depth of water - - - - -	**5** feet **6** inches.
Capacity of each - - - -	**70,000** gallons.
Total capacity - - - - -	**210,000** gallons.

Construction.—The low-level tanks are constructed of brick and cement walls with concrete bottoms, aad are fitted with sludge valves and floating arms. Each tank also contains a wall extending about two-thirds of its length along the centre of the tank.

Precipitant.—The general precipitant used for the low level sewage is Alumino-ferric. The quantity added is equivalent to about **6** grains per gallon on the dry weather flow.

On the days of strongest sewage (Tuesdays, Wednesdays and Thursdays), a solution of Copperas, equivalent to about **·5** to **·75** grain of crystallised salt per gallon, is also added to the low level sewage.

Both precipitants are added in the form of solution, made by running town's water on to the solid substances, the resultant liquids being mixed with the sewage by means of baffle plates in the inlet channel.

Flow Through.—With the dry weather flow of **300,000** gallons per **24** hours through the two tanks generally in use at one time, the flow through would be once in **12** hours, at the rate of **3** inches per minute.

Working.—The working of the low level tanks is exactly the same as that of the high level tanks. Two tanks worked in series are in use at one time. No. **1** tank, which is always used as a first tank, is cleaned twice a week, on Monday and Friday. No. **2**, which is used alternately as a first and a second tank, is cleaned once a week, on Wednesday ; and No. **3**, which is always used as a second tank, is cleaned out once a month.

Sludging.—At the end of its period of use, the tank to be sludged is cut out of the series and allowed to rest for a few hours. The supernatant liquor is then run off by means of a floating arm and treated upon the smaller earth filters, the sludge being allowed to gravitate subsequently to a large sludge well. In this well both sludges are mixed together and then pumped up into furrows cut in the land, these furrows being covered over as soon as the sludge has dried sufficiently.

The total amount of liquid sludge (from high level and low level tanks together), removed from the tanks weekly, is about 400 tons. Approximately, nine acres of land are set apart for its disposal, the two halves being alternately sludged and cropped in successive years. The crops grown are mangold wurzel and cabbage.

The method is effective, and although some nuisance arises during the pumping of the sludge, and also as the sludge lies drying in the furrows, we have not considered it serious when taking the situation of the works into account.

We understand that the crops grown are good.

Precipitation Liquors.—Four sets of hourly samples, both of high level and low level precipitation liquor were examined, these having been drawn at the same times and under the same conditions as the hourly samples of sewage.

High Level Precipitation Liquor—Four Hourly Sets. Nos. 623, 3292, 3300 and 3308.	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(2·96 to 4·11)	3·51	(4)
Albuminoid Nitrogen	(0·40 to 0·44)	0·43	(3)
Total Organic Nitrogen	(0·60 to 0·74)	0·68	(4)
Total Nitrogen	(3·62 to 4·83)	4·04	(4)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	1·24 to 1·82)	1·48	(4)
,, ,, ,, ,, ,, *in 4 hours*	(4·29 to 6·08)	5·20	(4)
Chlorine	(5·94 to 7·52)	6·67	(4)
Solids in suspension	(3·50 to 7·60)	5·50	(4)
Solids by centrifuge (vols.)	(21·0 to 58·0)	42·0	(4)
Ratio of solids in suspension to centrifuge solids	(1:4·7 to 1:11·4)	1:7·8	(4)

A chance sample, No. 3,176, drawn in dry weather on June 29th, 1903, at 1.10 p.m. gave the figures:—Total nitrogen, 6·36; "Oxygen absorbed" in 4 hours, 4·77. Suspended solids, 4·0. It was thus more nitrogenous, but otherwise much the same in composition as the hourly samples.

Low Level Precipitation Liquor—Four Hourly Sets., Nos. 624, 3294, 3302 and 3310.	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(3·53 to 5·16)	4·54	(4)
Albuminoid Nitrogen	(0·39 to 0.80)	0·67*	(4)
Total Organic Nitrogen	(0·64 to 2·08†)	1·24	(4)
Total Nitrogen	(4·17 to 6·63†)	5·80	(4)
"Oxygen absorbed" at 27° C. (80° F.) *at onc*	(1·12 to 2·04)	1·67	(4)
,, ,, ,, ,, ,, *in 4 hours*	(4·34 to 7·87)	6·52	(4)
Chlorine	(6·80 to 8·94)	8·07	(4)
Solids in Suspension	(2·60 to 4·50)	3·70	(4)
Solids by Centrifuge (vols.)	(15·0 to 42·0)	30·0	(4)
Ratio of solids in suspension to Centrifuge solids	(1:5·9 to 1:11·7)	1:8·0	(4)

A *chance* sample of low level precipitation liquor, No. 3,175, drawn at 1 p.m., on June 29th, 1903, in dry hot weather, gave the figures:—

Total nitrogen	7·74
"Oxygen absorbed" *in 4 hours*	5·14
Suspended solids	2·84

* This figure is probably a little to high. † These two numbers are possibly rather too high.

Here, again, this sample was distinctly stronger in nitrogen than the hourly samples, but weaker as regards "oxygen absorbed" and suspended solids.

Lastly, two chance samples of *mixed tank liquors* (high and low level together), Nos. 3,025 and 3,177, drawn about 1 p.m. in October, 1902, and June, 1903, in dry weather, gave :—

"Oxygen absorbed" *in 4 hours* - - - - -	5·15 and 4·79
Solids in suspension (calculated from the centrifuge figures) - - - - -	3·0 approx. and 3·0 approx.

These mixed liquors, as measured by the above two tests, were thus of practically the same strength as the hourly samples.

Comparing the two precipitation liquors, we find, as in the case of the sewages, that the low level liquor is distinctly the stronger, excepting in the matter of suspended solids. In other words, the sewage with the greater quantity of solids has become the liquor with the lesser quantity, but in both cases the precipitation is fairly good. Apart from the fact that copperas is used as well as alumino-ferric in the precipitation of the low level sewage on certain days, the coarser solids in that sewage have evidently aided in the precipitation of the finer particles.

If, as in the case of the hourly samples of sewage, we average the figures of analysis of the hourly samples of high level and low level precipitation liquors, according to their relative volumes (650,000 and 300,000 gallons per 24 hours), we get a *mixed precipitation liquor* of the following composition, this being the liquor which the filters have to treat. It will be seen that it is not a very strong liquor organically, and that it is comparatively free from suspended matter. It has not been thought necessary here to differentiate between the last six sets and the whole eight sets together, though the difference is proportionally rather greater than in the case of the sewages.

Mixed Precipitation Liquor (Eight Hourly Sets). Parts per 100,000.	Average.
Ammoniacal Nitrogen - - - - - - - - - - - - - -	3·83
Albuminoid Nitrogen - - - - - - - - - - - - - -	0·51
Total Organic Nitrogen - - - - - - - - - - - - -	0·86
Total Nitrogen - - - - - - - - - - - - - -	4·60
"Oxygen absorbed" at 27°C. (80°F.) *at once* - - - - - - - - -	1·50
" " " " " *in 4 hours* - - - - - - - - -	5·61
Chlorine - - - - - - - - - - - - - - - -	7·11
Solids in suspension - - - - - - - - - - - - - -	4·93
Solids by centrifuge (vols). - - - - - - - - - - - - -	38·0
Ratio of solids in suspension to centrifuge solids - - - - - - - - -	1 : 7·9

Comparing (*a*) the eight hourly samples of the two precipitation liquors with the eight hourly samples of the corresponding sewages, and (*b*) the (calculated) mixed precipitation liquor with the (calculated) mixed sewage (eight samples of each), we get the following reduction in figures :—

Calculated on :—	High Level.	Low Level.	Mixed.
Total Nitrogen - - - -	19 per cent.	11 per cent.	14 per cent. reduction
"Oxygen absorbed" *in 4 hours* -	50 "	61 "	55 " "
Solids in suspension - - -	76 "	89 "	81 " "

Bacteriological Notes.—With one exception all the seven samples of precipitation liquor yielded positive results with ·00001 c.c. (100,000 per c.c.) with the B. coli and neutral red broth tests. As regards the B. enteritidis sporogenes test, two samples contained 10, four samples 100, and one sample 1000 spores of this anaerobe per c.c.

Description of the Sample.	Number of B. coli (or gas-forming coli-like microbes).	B.S.=Bile-salt glucose peptone test. N.R.=Neutral red broth test. In.=Indol test. L.P.M.=Lactose peptone milk test.	B. enteritidis sporogenes test.	Remarks.
623. Hendon high level precipitation liquor, 20/10/03.	100,000 (+ indol) (+ clot)	100,000 N.R.	100 not 1,000	
3292. Hendon high level precipitation liquor, 10/11/03.	100,000 (+ indol) (+ clot)	100,000 N.R.	100 not 1,000	
3300. Hendon high level precipitation liquor, 11/11/03.	100,000 (+ indol) (+ clot)	100,000 N.R.	10 not 100	
3175. Hendon low level precipitation liquor, 28/6/03.	—	100,000 N.R.	100 not 1,000	
3294. Hendon low level precipitation liquor, 10/11/03.	10,000 not 100,000 (+ indol) (+ clot)	10,000, not 100,000 N.R.	100 not 1,000	
3302. Hendon low level precipitation liquor, 11/11/03.	100,000 (= indol) (+ clot)	100,000 N.R.	1,000 not 10,000	
3310. Hendon low level precipitation liquor, 12/11/03.	100,000 (+ indol) (+ clot)	100,000 N.R.	10 not 100	

HIGH LEVEL PERCOLATING FILTERS.

Number - - - - - - 6.

Total area - - - - - 3·48 acres.

Total cubic content of filters in use in October, 1903 - - - - Approximately, 10,000 cube yards.

Depth of material (October, 1903) :—

New Filters :—

No. 1 bed, 4 feet deep.
No 4 bed, 3 feet 6 inches deep.
No. 6 bed, 4 feet 6 inches deep.

Old Filters :—

No. 2 bed, 2 feet deep.
No. 3 bed, 2 feet deep.
No. 5 bed, 2 feet deep.

Material (October, 1903) :—

Beds Nos. 1, 4 and 6 :—

Burnt ballast under 2 inches diameter, and over $\frac{3}{8}$ inch diameter.

Beds Nos. 2, 3 and 5 :—

12 inches burnt ballast covered with 12 inches of soil.

Distribution.—One concrete channel laid longitudinally on the surface of the material.

Underdraining (October, 1903).—Beds Nos. 1, 4 and 6 had four lines of 6-inch agricultural pipes, connecting to one 12-inch pipe. Beds Nos. 2, 3 and 5 had 4-inch agricultural pipes, 15 feet apart, connecting to one main 12-inch drain.

Age of Filters.—All the high level percolating filters were brought into use in 1887. Since then, however, they have been under reconstruction. In October, 1903, Nos. 1, 4 and 6 were reconstructed, and towards the end of the observations, in the summer of 1905, two more filters had been reconstructed.

Working.—The general plan of working the high-level filters is as follows :—

The total flow of mixed tank liquors is allowed to run into one of the reconstructed primary percolating filters from 6 a.m. to 9 p.m. every fourth day. The valve of the bed is partially closed during this time ; but, owing to the fact that the beds were not originally constructed to hold water, they do not properly fill, and the treatment, therefore, is partly percolating and partly contact. The effluent from the filter thus used is subsequently treated either in one of the two contact beds, upon the lower secondary percolating filter, or upon the night filter. It is obvious that the fault in this method of treatment lies in the lack of distribution. On the new filters, where the material is large, the precipitation liquor sinks straight down into the bed, hardly spreading over the material at all, and so into the drains. It is no doubt for this reason that the method of working the beds with closed or partially closed valves has been resorted to.

It is necessary to add, however, that in September, 1905, a 3-inch layer of "pea" gravel was put down over the surface of one of the beds, for the purpose of causing the on-flowing liquid to spread. We understand that this greatly improves the distribution, and that the whole of the remaining five beds are shortly to be treated in the same way.

With the old filters, on the other hand, the difficulty, owing to the fine soil on the top, is to get the precipitation liquor to percolate quickly enough through the bed. These filters, however, have become consolidated, and they are now seldom used.

Primary Percolating Filter Effluents.—Four sets of hourly samples and seven chance samples were examined. The hourly samples, Nos. 626, 3,295, 3,303 and 3,311, were drawn at the same time and under the same conditions as the hourly samples of sewage and precipitation liquor. They gave the following figures :—

	Parts per 100,000.	Average.	Number of Estimations.
Oxidized Nitrogen - - - - - - - -		0·0	(4)
Total Nitrogen - - - - - - - - -	(3·36)		(1)
"Oxygen absorbed" at 27°C. (80°F.) *at once* - - -	(0·88 to 1·26)	1·08	(4)
" " " " *in 4 hours* - -	(3·17 to 4·36)	3·88	(4)
Chlorine - - - - - - - - - -	(6·10 to 7·82)	6·97	(4)
Solids by centrifuge (vols.) - - - - - -	(8·4 to 20·0)	13·8	(4)
Incubator test (by smell) - - - - - - -		2 –	(2)
Smell when drawn - - - - - - - -		4 –	(4)
Smell when analysed - - - - - - -		4 –	(4)

In appearance these hourly samples of effluent were opalescent and slightly brown and turbid, with more or less of a sewage smell. In no case, however, did they contain much suspended matter—not more than about 2 to 3 parts per 100,000, as judged by the centrifuge figures. Speaking generally, these effluents were very uniform in composition, the average figure for "oxygen absorbed" in 4 hours being 3·88. None of them contained any oxidized nitrogen on the day of analysis, and it may be said that none withstood incubation (only two were actually tested for this).

The primary percolating filters thus do not effect a very great reduction in the impurity of the precipitation liquor. Hence, the liquid which the secondary percolating and secondary contact filters have to treat is—for secondary filters—a somewhat strong one organically, with the important exception that it contains very little solids in suspension.

As compared, respectively, with the four sets of hourly samples of sewage and of precipitation liquor, these four sets of hourly samples of primary percolating filter effluent show the following reduction in figures :—

SEWAGE.

Calculated on :—	High Level.	Low Level.	Mixture of the two sewages in the proportion of 6·5 High Level to 3·0 Low Level, by volume.
Oxygen absorbed *at once* - -	58 per cent.	74 per cent.	63 per cent. reduction
,, ,, *in 4 hours* - -	63 ,,	77 ,,	67 ,, ,,
Solids by centrifuge (vols.) - -	94 ,,	96 ,,	95 ,, ,,

PRECIPITATION LIQUOR.

Calculated on :—	High Level.	Low Level.	Mixture of the two sewages in the proportion of 6·5 High Level to 3·0 Low Level, by volume.
Oxygen absorbed *at once* - -	27 per cent.	34 per cent.	29 per cent. reduction
,, ,, *in 4 hours* - -	30 ,,	41 ,,	33 ,, ,,
Solids by centrifuge (vols.) - -	67 ,,	54 ,,	62 ,, ,,

The seven chance samples of primary percolating filter effluent examined, Nos. 3026, 481, 3177A, 3417, 704, 3539 and 3655, were drawn between the months of February and October, *i.e.*, none of them in the coldest months of the year. Five of them were taken between 1.22 p.m. and 4.30 p.m., and the remaining two at 2 a.m. and 3 a.m. These last two represented the liquid treated on the night beds, and it is noteworthy that they gave higher figures for "Oxygen absorbed" from permanganate than any of the five day samples.

The following figures were obtained :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - - - - -	(2·87 to 5·49)	4·36	(5)
Albuminoid Nitrogen - - - - - - - -	(0·30 to 0·76)	0·50	(4)
Oxidized Nitrogen - - - - - - -	(0·0 to 1·28 approx.)	0·27 approx.	(6)
"Oxygen absorbed" at 27°C. (80°F.) *at once* - - -	(0·77 to 1·80)	1·20	(7)
,, ,, ,, ,, *in 4 hours* - -	(2·07 to 5·38)	3·84	(7)
Dissolved Oxygen taken up in 24 hours at about 18°C. -	(0·48 to 7·00)	* 2·5 approx.	(4)
Chlorine - - - - - - - - - - -	(7·22 to 10·50)	9·11	(3)
Solids in suspension - - - - - - - - -	(3·20 and 2·70)		(2)
Solids by centrifuge (vols.) - - - - - - -	(1·1 to 33·0)	18·10	(7)
Ratio of Solids in suspension to centrifuge solids	(1 : 5·7 and 1 : 3·3)		(2)
Incubator Test (Scudder) - - - - - - - - -	- 1 + 4 -		(5)
,, ,, (by smell) - - - - - - - - -	- 1 + 6 -		(7)
Smell when drawn - - - - - - - - -	- 1 (?) 3 -		(4)
Smell when analysed - - - - - - - -	- 1 + 3 (?) 3 -		(7)

* This figure is really too low; in two cases all the oxygen present was exhausted.

In appearance these effluents were partly opalescent and partly brown and turbid, and half of them, at least, had more or less of a sewage smell when drawn.

One of them had a fishy—earthy smell on the day of analysis, but the others had either a suspicious, or a sewage odour. Only two of the seven contained any oxidized nitrogen (0·3 and 1·3 parts approximately), and only one withstood incubation.

As regards suspended solids, all but two of them contained more than the hourly samples, as judged by the centrifuge figures.

Comparing the above effluents with the (calculated) *mixed* precipitation liquor from the eight sets of hourly samples, we get the following reduction in figures :—

Calculated on :—	Reduction.
"Oxygen absorbed" *at once* - - - - - - - - - - -	20 per cent.
" " *in 4 hours* - - - - - - - - - -	32 "
Solids by centrifuge (vols.) - - - - - - - - - - -	53 "

The above results thus agree substantially with those obtained from the hourly samples. They show that, excepting as regards the removal of suspended solids, the purification effected by the primary percolating filters is not very great.

Bacteriological Notes.—Generally speaking, the effluents yielded positive results with from ·0001 to ·00001 c.c. (10,000 to 100,000 per c.c.) with the B. coli test and presumptive tests for B. coli. All the six samples yielded positive results with ·01 c.c. (100 per c.c.) with the B. enteritidis sporogenes test.

Description of the Sample.	Number of B. coli. (or gas-forming coli-like microbes).	B.S.=Bile salt glucose peptone test. N.R.=Neutral red broth test. In.=Indol test. L.P.M.=Lactose peptone milk test.	B. Enteritidis sporogenes test.	Remarks.
481. Hendon primary percolating filter effluent, 4/2/03	100,000 (+ indol) (+ clot)	100,000 N.R. 100,000 In.	100 not 1,000	5,700,000 microbes (gelatine at 20°C.). Gas test + ·01 c.c. (24 hours at 20° C.).
3177A. Hendon primary percolating filter effluent, 29/6/03	—	100,000 N.R.	100 not 1,000	
626. Hendon primary percolating filter effluent, 20/10/03	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R.	100 not 1,000	
3295. Hendon primary percolating filter effluent, 10/11/03	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R.	100 not 1,000	
704. Hendon primary percolating filter effluent, 7/6/04	1,000 not 10,000 (+ indol) (+ clot)	1,000 not 10,000 B.S. 10,000 not 100,000 N.R.	100 not 1,000	
3539. Hendon primary percolating filter effluent, 16/8/04	100,000 (+ indol) (+ clot)	100,000 B.S. 100,000 N.R.	100 not 1,000	

SECONDARY PERCOLATING FILTER.

Number	One.
Size	128 feet by 56 feet 6 inches.
Superficial area	800 square yards.
Depth	About 5 feet.
Cubic content	1,324 cube yards.
Construction	Cement concrete throughout.
Material (Top)	9 inches of coke breeze, $\frac{3}{16}$ inch to $\frac{1}{8}$ inch diameter.
(Middle)	2 feet of pan breeze, over $\frac{3}{16}$ inch diameter. 2 feet of burnt ballast, over $\frac{3}{16}$ inch diameter.
(Bottom)	9 inches of brick rubbish.

Distribution.—The liquid is spread over this filter by means of fine surface material alone. There are no grips or channels on the bed.

Underdraining.—Thirteen rows of 9-inch perforated pipes, draining to one 18-inch perforated pipe.

Age of Filter.—The secondary percolating filter was started in January, 1899.

Working.—As has been already stated, the whole of the mixed tank liquors is first passed through one of the primary percolating filters. The effluent is then, for the most part, treated in secondary contact beds from 6 a.m. to 9 p.m. each day, and on the night bed from 9 p.m. to 6 a.m. The excess of primary percolating filter effluent in the day time (*i.e.*, from 6 a.m. to 9 p.m.), which cannot be treated in the contact beds, is streamed through the secondary percolating filter now under consideration. As a rule, therefore, this filter is used as a streaming filter from 6 a.m. to 9 p.m. each day. The quantity treated in this way cannot be given definitely, as it continually varies.

The plan of working this bed as a continuous filter is of special interest, in that it enables the contact beds to be worked steadily and to give a stipulated period of contact, whatever the rate of flow of high level percolating filter effluent.

Secondary Percolating Filter Effluents.—Four hourly sets of samples and one chance sample were examined chemically. The hourly sets were drawn in October and November, 1903, at the same time and under the same conditions as the other hourly samples already described; it should, however, be mentioned that No. 628 was made up of six equal bi-hourly portions, taken between 7 a.m. and 6 p.m., Nos. 3297 and 3304 each of twelve equal hourly portions, taken between 9.30 a.m. and 8.30 p.m., and No. 3313 consisted of hourly portions taken over the whole 24 hours of a day.

The following figures were obtained:—

Parts per 100,000.		Average.	Number of Estimations.
Ammoniacal Nitrogen	(1·06 to 1·81)	1·41	(4)
Albuminoid Nitrogen	(0·08 to 0·13)	0·10	(4)
Oxidized Nitrogen	(0·83 to 2·16)	1·43	(4)
"Oxygen absorbed" at 27°C. (80°F.) *at once*	(0·33 to 0·54)	0·40	(4)
" " " " *in 4 hours*	(1·45 to 1·50)	1·48	(4)
Chlorine	(5·70 to 7·60)	6·66	(4)
Solids by Centrifuge (vols.)	(2·5 to 11·4)	5·1	(4)
Incubator Test (Scudder)	(practically 4 +)		(4)
" " (by smell)	(4 +)		(4)
Smell when drawn	(4 +)		(4)
Smell when analysed	3 + 1 — (?)		(4)

In appearance these effluents were faintly opalescent, with a slight brownish tint, and, excepting for a small quantity in No. 628, they were practically free from suspended matter. Three of them were noted as having a cabbage-water smell when drawn, but they all—excepting possibly one—had an earthy smell when analysed, and they all easily withstood incubation. Taking them all over, they were of pretty uniform composition and of very fair quality, and they showed a good percentage purification on the corresponding sewage and precipitation liquor; still, though they had an average of 1·4 parts of oxidized nitrogen to an equal quantity of ammoniacal nitrogen, the analyses indicated the presence of a small quantity of readily oxidizable organic matter—sufficient to prevent these being called effluents of high class.

Compared with the (calculated) mixed sewage and mixed precipitation liquor (the eight sets of hourly samples in each case), these effluents show the following percentage reduction in figures :—

Calculated on :—	Mixed Sewage.	Mixed Precipitation. Liquor.
Ammoniacal Nitrogen - - - - - - - - -		63 per cent. reduction
Albuminoid Nitrogen - - - - - - - -		80 ,, ,,
"Oxygen absorbed" *at once* - - - - - - - -	87 per cent.	73 ,, ,,
,, ,, *in* 4 *hours* - - - - - - -	88 ,,	74 ,, ,,
Solids by centrifuge (vols.) - - - - - - - -	98 ,,	86 ,, ,,

The chance sample of secondary percolating filter effluent examined, No. 3418, was drawn on Monday, March 8th, 1904, at 3 p.m., from a bed which had started working at 7 a.m., after resting all night. This was of the same character as the hourly samples, though not quite so good. Here, again, there was but a trace of suspended matter present.

An important result, therefore, of the treatment at Hendon on the percolating filters is that nearly the whole of the suspended matter is removed from the effluent before it is finally discharged.

Bacteriological Notes.—The samples yielded positive results with from ·01 to ·001 c.c. (100 to 1,000 per c.c.) with the B. coli and neutral red broth tests. As regards the B. enteritidis sporogenes test, one sample contained 10, but the other three samples contained only 1 spore of this anaerobe per c.c. Bacteriologically, the secondary percolating filter effluents were better than the contact bed effluents.

Description of the Sample.	Number of B. Coli (or gas-forming Coli-like Microbes).	B.S.=Bile-salt Glucose Peptone Test. N.R.=Neutral Red Broth Test. In.=Indol Test. L.P.M.=Lactose Peptone Milk Test.	B. Enteritidis Sporogenes Test.	Remarks.
628. Hendon secondary percolating filter effluent, 20/10/03.	1,000 not 10,000 (+ indol) (+ clot)	1,000 not 10,000 N.R.	10 not 100	
3297. Hendon secondary percolating filter effluent, 10/11/03.	1,000 not 10,000 (— indol) (+ clot)	1,000 not 10,000 N.R.	1 not 10	
3304. Hendon secondary percolating filter effluent, 11/11/03.	100 not 1,000 (+ indol) (+ clot)	100 not 1,000 N.R.	1 not 10	
3418. Hendon secondary percolating filter effluent, 6/3/04.	1,000 not 10,000 (+ indol) (+ clot)	1,000 not 10,000 N.R.	1 not 10	

CONTACT BEDS.

Number - - -	2.
Size of each - - -	128 feet by 56 feet 6 inches.
Area of each - - -	800 square yards.
Total area - - -	1,600 square yards.
Depth of material - -	About 5 feet.
Total cubic content -	2,666 cube yards.
Construction - - -	Cement concrete throughout.
Material - - -	No. 1 (Top)—6 inches fine ballast, $\frac{1}{8}$ inch diameter. 2 feet 6 inches pan breeze, over $\frac{3}{16}$ inch diameter. 12 inches burnt ballast, over $\frac{1}{2}$ inch diameter. (Bottom)—9 inches brick rubbish. No. 3 (Top)—2 feet 3 inches pan breeze, over $\frac{3}{16}$ inch diameter. 3 inches burnt ballast, over $\frac{3}{16}$ inch diameter. 1 foot 9 inches pan breeze, over $\frac{3}{16}$ inch diameter. (Bottom)—9 inches brick rubbish.
Distribution - -	No. 1 bed:—One line of 18-inch half pipes, laid on the surface of the material down the centre of the bed. No. 3 bed:—No distribution.
Underdraining - -	No. 1 bed:—Thirteen rows of 6-inch perforated pipes, draining to one 18-inch perforated pipe. No. 3 bed:—Thirteen rows of 9-inch perforated pipes, draining to one 18-inch perforated pipe.

Age of Beds.—No. 1 was started in September, 1898; No. 3 in December, 1900.

Working.—The two contact beds receive the larger portion of the effluent from one of the high level percolating filters each day, from 6 a.m. to 9 p.m. They rest during the night.

In dry weather they fill in about two hours, and give a contact of two hours. The quantity treated is equivalent to an average of $2\frac{1}{2}$ fillings for each bed per day.

Capacity.—No capacity measurements of the contact beds have been made, but as they are in perfectly good condition and fill in approximately the same time as they did when they were first brought into use, it may be taken that no serious loss of capacity has occurred as the result of their five years working, at an average rate of about $2\frac{1}{2}$ fillings per day.

Secondary Contact Bed Effluents.—Here, again, 4 sets of hourly samples and 1 chance sample were examined. The hourly samples, Nos. 627, 3,296, 3,305, and 3,312 were drawn on the same days as the hourly samples of secondary percolating filter effluent. No. 627 was made up of effluent from 2 emptyings and the other three of effluent from 3 emptyings of the beds; in every case this was drawn at mid-flow.

The following figures were obtained :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - - - - -	(1·44 to 2·03)	1·71	(4)
Albuminoid Nitrogen - - - - - - - -	(0·08 to 0·21)*	0·15	(4)
Oxidized Nitrogen - - - - - - - -	(0·95 to 1·45)	1·23	(4)
"Oxygen absorbed" at 27° C. (80° F.) *at once* - - -	(0·33 to 0·68)	0·51	(4)
,, ,, ,, ,, *in 4 hours* - - -	(1·34 to 2·32)	1·89	(4)
Chlorine - - - - - - - - - -	(6·50 to 7·82)	6·96	(4)
Solids by Centrifuge (Vols.) - - - - - - -	(7·0 to 10·4)	8·4	(4)
Incubator Test (Scudder) - - - - - - -	(2 + 2 −)		(4)
Incubator Test (by smell) - - - - - - - -	(4 +)		(4)
Smell when drawn - - - - - - - - -	(4 +)		(4)
,, ,, analysed - - - - - - - - -	(4 +)		(4)

The above secondary contact bed effluents were faintly opalescent, with a yellowish tint; and, like the secondary percolating filter effluents, they contained very little suspended solid. Three of them were noted as having a cabbage-water smell when drawn, while on the day of analysis one had an earthy and the others a more or less fishy smell. They were all fairly well nitrated, in proportion to the total nitrogen present, and they all withstood incubation. At the same time the general results of the examination indicate that the oxidation of the organic matter present was by no means carried to its fullest extent, and these effluents can therefore only be classed as of moderate quality. They were not, on the whole, quite so good as the hourly samples of secondary percolating filter effluent.

Compared with the (calculated) *mixea* sewage and *mixed* precipitation liquor (8 sets of hourly samples in each case), the secondary contact bed effluents show the following percentage reduction in figures :—

Calculated on :—	Sewage.	Precipitation Liquor.
Ammoniacal Nitrogen - - - - - - - - -		55 % reduction
Albuminoid Nitrogen - - - - - - - - -		71 ,, ,,
"Oxygen absorbed" *at once* - - - - - - - -	84 % reduction	67 ,, ,,
,, ,, *in 4 hours* - - - - - - - -	85 ,, ,,	66 ,, ,,
Solids by Centrifuge (Vols.) - - - - - - - -	97 ,, ,,	68 ,, ,,

The chance sample of secondary contact bed effluent examined, No. 3,419, drawn in March, 1904, after a contact of 3 hours, was of much the same composition as the hourly samples.

* Possibly a little too high.

Bacteriological Notes.—The samples yielded positive results with from ·001 to ·0001 c.c. (1,000 to 10,000 per c.c.) with the B. coli and neutral red broth tests. All four samples contained 10, but not 100 spores of B. enteritidis sporogenes per c.c.

Description of the Sample.	Number of B. coli (or gas-forming coli-like microbes).	B.S.=Bile salt glucose peptone test. N.R.=Neutral red broth test. In.=Indol test. L.P.M.=Lactose peptone milk test.	B. Enteritidis sporogenes test.	Remarks.
627. Hendon contact bed effluent 20/10/03	10,000 not 100,000 (— indol) (+clot)	10,000 not 100,000 N.R.	10 not 100	
3,296. Hendon contact bed effluent 10/11/03	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R.	10 not 100	
3,305. Hendon contact bed effluent 11/11/03	1,000 not 10,000 (+ indol) (+ clot)	1,000 not 10,000 N.R.	10 not 100	
3,419. Hendon contact bed effluent 6/3/04	1,000 not 10,000 (+ indol) (+ clot)	1,000 not 10,000 N.R.	10 not 100	

NIGHT FILTER.

At night, the whole flow of tank liquor, after passing through one of the high level percolating filters, is turned in dry weather on to a plot of land, having an area of about 1½ acres, which is artificially made up on the top with 12 inches of burnt ballast. This land is called the Night Filter. It is not under-drained, and the only system of distribution is by means of grips cut in the ballast. As, therefore, the effluent is delivered at one end, the filtration given to it is in a lateral direction towards the outlet at the opposite side of the plot.

The bed receives high level percolating filter effluent from 9 p.m. to 6 a.m. each night in dry weather. It is not used on wet nights.

Night Filter Effluents (Secondary).—In order to gain some idea of how this treatment compared with the day treatment on the secondary percolating filters and secondary contact beds, four night-filter effluents were examined. These four were drawn on two nights only, but at different hours of the night, while in each case a sample of roughly corresponding primary percolating filter effluent was taken at an hour midway between those of the two night effluents. On both occasions the weather was dry, or practically so.

The samples were :—

Primary percolating filter effluent, No. 3,539, drawn Tuesday, Aug. 16th, 1904, at 2 a.m.
Secondary night effluent, No. 3,538 ,, Monday, Aug. 15th, 1904 ,, 11 p.m.
Secondary night effluent, No. 3,540 ,, Tuesday, Aug. 16th, 1904 ,, 6 a.m.
Primary percolating filter effluent, No. 3,655 ,, Friday, Oct. 6th, 1905 ,, 3 a.m.
Secondary night effluent, No. 3,656 ,, Thursday, Oct. 5th, 1905 ,, 12 mid.
Secondary night effluent, No. 3,657 ,, Friday, Oct. 6th, 1905 ,, 5 a.m.

The individual samples of each pair of night filter effluents were almost identical in chemical composition, so their figures have been averaged and placed beside the figures of the corresponding primary percolating filter effluent.

Parts per 100,000.	Primary Effluent, No. 3539.	Secondary Night Filter Effluents, Nos. 3538 and 3540 (Average of).	Primary Effluent, No. 3655.	Secondary Night Filter Effluents, Nos. 3656 and 3657 (Average of).
Ammoniacal Nitrogen - - - - -	5·34	4·07	5·49	3·25
Albuminoid Nitrogen - - - - - -	0·51	0·44		0·29
Total Organic Nitrogen - - - - -				0·67
Oxidized Nitrogen - - - - - -	0·0	0·0	0·0	0·70
Total Nitrogen - - - - - - -				4·62
"Oxygen absorbed" at 27° C. (80° F.) *at once* -	1·80	1·38	1·70	0·83
" " " " *in* 4 *hours* -	5·38	4·26	5·25	3·01
Dissolved oxygen taken up in 24 hrs. at about 18°C			6·60	2·01
Chlorine - - - - - - - -			9·60	9·26
Solids in Suspension - - - - - -	3·20		2·70	
Solids by Centrifuge (vols.) - - - -	18·3	8·7	9·0	5·0
Incubator Test (Scudder) - - - - -	—			
Incubator Test (by smell) - - - - -	—	—	—	—
Smell when drawn - - - - - -		+ —		
Smell when analysed - - - - - -	—	? ?	—	+ +

The primary effluent, No. 3655, which may be taken as representing approximately the average liquor treated on the night filters in dry October weather, was by no means very weak, but it had only 2·7 parts of suspended solids. The other primary effluent, No. 3539, drawn in dry weather in the month of August, had practically the same composition.

The first pair of night filter effluents showed comparatively little purification upon the original primary effluent; they contained no oxidized nitrogen and failed to withstand incubation. The second pair were distinctly better; although failing at the incubator test, they each contained about 0·7 part of oxidized nitrogen, and they had a clean smell both when drawn and when analysed.

These night samples could not compare in quality with either the secondary percolating filter or secondary contact bed day effluents. It will be noted that the primary effluents treated by the night filters on these two occasions were distinctly stronger organically than the average of all the seven primary percolating filter effluents examined.

Bacteriological Notes.—Both samples yielded positive results with ·00001 c.c. (100,000 per c.c.), with the B. coli test and the presumptive tests for B. coli. Both samples contained 100 spores of B. enteritidis sporogenes per c.c.

Description of the Sample.	Number of B. coli (or gas-forming coli-like microbes).	B.S.=Bile-salt glucose peptone test. N.R.=Neutral red broth test. In.=Indol test. L.P.M.=Lactose peptone milk test.	B. enteritidis sporogenes test.	Remarks.
3538. Hendon night filter effluent, 15/8/04	100,000 (+indol) (—clot)	100,000 B.S. 100,000 N.R.	100 not 1,000	
3540. Hendon night filter effluent, 16/8/04	100,000 (+indol) (+clot)	100,000 B.S. 100,000 N.R.	100 not 1,000	

Amount of Precipitation Liquor treated.—The total area of high level percolating filters, contact beds, and night filter, which together constitute the general filtration process, is 25,660 square yards; and the cubic contents in 1903 were estimated at 16,420 cube yards.

On the basis of a dry weather flow of 950,000 gallons per day, therefore, the amount treated at this time was at the following rates:—

Per square yard per 24 hours - - - -	37 gallons.
Per cube yard per 24 hours - - - -	57 gallons.

It must be remembered, however, that the actual rate of treatment at any given time is much greater than this, as only one of the large percolating filters is ever in use, and the contact beds and the night filter are used alternately each day and night. The actual rate of treatment in dry weather is probably from 200 to 250 gallons per square yard per day.

SUMMARY.

Subsoil water appears to find its way into both high level and low level systems of sewers, but the mixed liquids constitute a sewage of distinctly over the average strength, excepting as regards suspended solids, which are not high.

The precipitation effected in the two sewages is good, both relatively and actually; the dry-weather hourly samples of high level precipitation liquor contained an average of 6·1 parts of suspended solids and the corresponding low level samples an average of 4·1 parts per 100,000. The quantity of precipitant used is not large, being about 5 grains per gallon in the case of the high level and 6 to 7 grains in that of the low level sewage, and we think that the good results obtained are due mainly to the following causes:—(1) the method of adding the precipitant; (2) the frequent sludging of the primary tanks; (3) the long "flow through" the tanks (12 hours); and (4) the care and attention given to the process in all its details. Possibly, too, the mode of construction of the tank, *i.e.* the presence of a dividing wall extending down it for about two-thirds of its length, contributes also. Further, there is practically no preliminary grit settlement, and the presence of the grit in the liquid under precipitation no doubt assists the clarifying process to some extent. It is interesting to note that the sewage with the larger quantity of solids becomes the precipitation liquor with the smaller quantity.

The large and deep sludge well at Hendon allows of the removal of about 400 tons of liquid sludge from the tanks, per week, being carried out rapidly and without much nuisance at the works. The subsequent disposal of the sludge by pumping it on to land and digging it in, after it has dried sufficiently in the furrows, is both effective and economical. The only disadvantage of this procedure is that in some weathers considerable nuisance from smell arises during the drying in the open. Hence the method is one which could not properly be employed if there were houses in the vicinity. We understand from the Surveyor to the Hendon District Council that this method of sludge disposal compares very favourably, as regards working costs, with the lime-pressing process formerly in use. While lime-pressing cost 4/3 per ton of pressed cake, or 10d. per ton of wet sludge, the disposal by the present system costs only about 3d. per ton of wet sludge.

The sludge is also stated to have improved the quality of the clay land to which it has been applied, and to have produced excellent crops of mangolds, etc.

Excepting as regards suspended solids, the primary percolating filters do not effect a very great purification of the precipitation liquor. This, we think, is due to the defective distribution on the beds, as reconstructed. The liquor now sinks rapidly into them, near to the point where it is delivered, and, consequently, if the outlet valve is kept open, it finds its way, more or less directly, into the under-drains and so out of the bed. With a view of obviating this, the beds are now used partly on the contact system, that is, as streaming filters with the valve almost closed; but, owing to the construction of the filter tanks by simple excavation, they leak considerably when filled above a certain level, and hence it is impossible to thoroughly hold up the liquid in them.

In the old primary filters a layer of earth was spread over the burnt ballast and the distribution was therefore fairly good. It may be noted, in passing, that these filters were only 2 feet deep, whereas the depth of the new ones is 4 feet. Apart from the

desire to have greater depth, the reason for altering the principle of construction was that the earth surface of the old filters became clogged, though only after about 16 years' work; the drains, too, were found to be choked, from the gradual disintegration of the ballast. As events have shown, it would probably have been better to have re-made the filters on the old principle, that is to say, with a layer of some fine filtering medium on the surface. We understand that steps are now (1906) being taken to do this.

But, notwithstanding the comparatively small purification which the primary filters effect on the liquid portion of the precipitation liquor, they have the important result of still further reducing the already moderate quantity of the suspended solids of the precipitation liquor, so as to leave very little of these for the secondary beds to deal with. As a consequence of this the secondary beds, both contact and percolating, appear to be in much the same condition now as when they were started, five years ago.

In regard to the primary filters, it is important to notice that the renewal was made by re-burning the old material, so far as it went. The original excavation was, of course, comparatively inexpensive, while the cost of complete renewal—including the deepening of the filters, the sifting and carting away of the fine material, and the re-laying of the drains—came to about 3s. 6d. per cube yard.

The secondary percolating filter effluents examined were of very fair quality and very free from suspended matter. Had the purification on the primary beds been greater, these secondary effluents would probably have been effluents of high class. In regard to the construction of the secondary percolating beds, we think that, unless it be with the object of utilising filtering material ready to hand, it is unnecessary to go into the refinements of grading followed at Hendon; and this remark applies to the construction of the contact beds also.

The secondary contact bed effluents were of moderate quality—not so good as those from the secondary percolating filters. One reason for this, no doubt, was because the contact beds were treating a larger volume of effluent per cube yard, at an average rate of $2\frac{1}{2}$ fillings per day.

We have been unable to make any gaugings at Hendon, but the contact beds are still in perfectly good condition after 5 years' work, and it may be taken that they have not undergone any serious loss of capacity.

Secondary Night Filter Effluents.—Only four samples of these, taken on two nights, were examined, and we can therefore only speak of this process with reserve. But, so far as our results go, they show that the primary effluent treated on the night filters is organically quite as strong as that treated by day, while the night filter effluents are not nearly of such good quality as the others. The night filter, which is only 1 foot deep, was originally fed from a side channel only, and the liquid found its way to the outlet along the bottom of the bed; now there are many more channels for distribution, and the effluent is consequently improving in quality. It seems doubtful, however, whether such a shallow filter would ever give really satisfactory results unless with a very small flow of liquid, for it is obvious that any error of distribution must be relatively magnified upon it.

While the tanks are being emptied of sludge there is occasionally a local smell and in certain states of the weather the smell may become very pronounced from that portion of the land where the wet sludge is drying in the furrows. But apart from this, the works may be said to be reasonably free from nuisance.

In conclusion, it is hardly necessary to say that the system of sewage treatment followed at Hendon is a very complex one—complex because of modifications introduced from time to time, with the object of improving on an older system which had gradually become inadequate. It says much, therefore, for the present management that the effluents produced, at all events the day effluents, keep up to a fairly good standard. And, although the process lends itself to criticism in respect to details, its general result is a good purification of a distinctly strong sewage.

We are indebted to Mr. S. S. Grimley, Surveyor to the Hendon Urban District Council, and also to Mr. John Choate, Manager of the Sewage Works, for help in connection with our observations at Hendon.

HENDON.

"DUCAT" FILTER EXPERIMENTAL PROCESS.

The original experiments carried out by the late Colonel Ducat, which resulted in the design of the "Ducat" Continuous Aerated Filter were made upon the high level sewage at Hendon. They began in 1896 with small experimental filters composed of coke, and constructed in such a way as to carry out Colonel Ducat's main ideas with regard to the biological treatment of fresh sewage by percolation through fine filtering material, the filter having open sides and also a free base with the object of inducing the best aeration possible.

A provisional patent was taken out on January 9th, 1897, claiming that the discovery consisted "essentially in constructing the sides of the structure containing the filtering medium of open work—affording access for the ambient air to the filtering medium so as to permit of the air penetrating the pores or interstices thereof under the exhaustive action due to the motion of the water between and through the particles of the filtering medium."

A larger filter (15 feet by 12 feet by 8 feet deep) was built in May, 1897, and used for comparative experiments, in which three kinds of material were successively employed coke being used first, then gravel, and lastly clinker.

In 1898 a second filter (15 feet by 12 feet by 10 feet deep) was constructed, and after several alterations to both filters, they commenced working in their present form (1905) towards the end of 1899, the actual months being August, 1899, for No. 1 filter, and November, 1899, for No. 2 filter.

The Sewage.

The sewage treated upon each of the filters is taken from the Hendon high level sewer by a $1\frac{1}{2}$-inch pipe, let into the sewer 4 inches from the bottom and carried about 4 inches into the flow. Both pipes are set at right angles to the flow, and have $\frac{1}{2}$-inch screens fitted over the ends.

In consequence of the setting of these pipes, and probably also owing to the very small flow which is taken through the controlling stop-cock, the sewage delivered to the filters contains rather less suspended matter than the average high level sewage. It is, however, delivered to the filters without settlement of any kind, though, as previously stated, it is passed through screens having a $\frac{1}{2}$-inch mesh.

As the water level in the high level sewer fluctuates considerably, the flow, as treated upon the Ducat filters, also varies. These variations, however, are comparatively small, and are spread over a considerable period of time. During our gauging of the flow on to the Ducat filters in dry weather, the greatest variation recorded was in the proportion of two to one, and was spread over a period of twelve hours. Probably it never varies in a proportion of much more than three to one.

Crude Sewage.—Three sets of hourly samples and nine chance samples were examined chemically. The hourly sets, Nos. 600, 602 and 605, were drawn according to rate of flow during dry weather in the middle of September, 1903 (Monday to Thursday), and they may, we think, be taken as fairly representative of the dry-weather sewage of the year. At the same time a sample of weak night sewage, No. 604, drawn on Wednesday, September 16th, 1903, at 4 a.m., was examined.

The following results were obtained :—*

	Parts per 100,000.	Average.	Number of Estimations.	No. 604. Weak Night Sewage.
Ammoniacal Nitrogen - - - - -	(4·47 to 5·10 ?)	4·83	(3)	3·40 ap.
Albuminoid Nitrogen - - - - -	(0·93 ? to 1·15)	1·02	(3)	
Total Organic Nitrogen - - - -	(2·03)		(1)	
Oxidized Nitrogen - - - - - - - -		0·0	(3)	Very slight trace.
Total Nitrogen - - - - - -	(6 15 ? and 6·50)		(2)	
"Oxygen absorbed" at 27° C. (80° F.) *at once* -	2·37 to 2·77)	2·54	(3)	0 79
" " " " *in 4 hours* -	(9·89 to 13·45)	11·75	(3)	2·89
Chlorine - - - - - - - -	(7·80 to 8·70)	8·30	(3)	
Solids in Suspension - - - - -	(16·70 to 24·10)	20·10	(3)	1·00·
Containing Mineral matter - - - -	(3·60 to 6·20)	4·70	(3)	0·10
Solids by Centrifuge (vols.) - - - -	(141·0 to 215 0)	181·0	(3)	7 0
Ratio of solids in suspension to centrifuge solids	(1 : 8·4 to 1 : 9·5)	1 : 8·9	(3)	1 : 7·0
Incubator test (by smell) - - - - - - -				—

The above hourly sets were fairly uniform in composition, though the sample drawn from Tuesday to Wednesday was the strongest, and they represented a soapy sewage of rather over average strength, but with less than an average quantity of suspended solids, these being rather flocculent; they all had a soapy, as well as a sewage smell. The weak night sample, No. 604, was milky looking, but almost free from suspended matter. For a night sample it was rather strongly ammoniacal and it, too, had a soapy smell. About thirty hours elapsed between the time when this sample was drawn and the time when it was analysed, so, although it showed no nitrite or nitrate, it may possibly have contained some in the first instance. Probably, however, there was not much subsoil water gaining access to the sewers at the time.

Chance Samples.—Of the eight ordinary chance samples of crude sewage examined, five, Nos. 1, 3, 5, 7 and 9, were drawn between December, 1898, and May, 1899, while the other three, Nos. 514, 544 and 727, were drawn in April and June, 1903, and October, 1904. They were all taken between 10.40 a.m. and 3 p.m. (most of them between 11 a.m. and 1.30 p.m.), and therefore represented the strongest sewage of the day. Excepting Nos. 7 and 514, all the eight were dry-weather samples. No weather notes were made at the time the earlier samples of sewage and effluent were drawn, but through the kindness of Dr. H. R. Mill, of "British Rainfall," the weather records at or near Hendon on the dates in question and for the week preceding those dates have been placed at our disposal.

These samples gave the following results :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - - - - -	(6·12 to 9·03)	7·40	(7)
Albuminoid Nitrogen - - - - - - - -	(1·49 to 2·17)	1·85	(7)
Total Organic Nitrogen - - - - - - -	(2·89 to 4·34)	3·76	(6)
Oxidized Nitrogen - - - - - - - -	(0·0 to trace)	0·0	(4)
Total Nitrogen - - - - - - - - -	(6·62 to 12·81)	10·45	(7)
"Oxygen absorbed" at 27° C. (80° F.) *at once*† - - -	(1·99 to 7·92)	4·72	(7)
" " " " *in 4 hours* - -	(9·11 to 22·73)	15·20	(8)
Chlorine - - - - - - - - - - - -	(9·80)		(1)
Solids in Suspension - - - - - -	(55·2 in No. 727)		(1)
Containing mineral matter - - - - - -	(12·7 in No. 727)		(1)
Solids by centrifuge (vols.) - - - - - -	(132·0 to 482·0)	363·0	(3)
Ratio of solids in suspension to centrifuge solids - - - -	(1 : 8·6)		(1)
Dissolved Gases (c.c. per litre) :—			
Free Carbon Dioxide - - - - - - - -	(31·5 and 48·5)		(2)
Total Carbon Dioxide - - - - - - - -	(197·8 in No. 3)		(1)
Nitrogen - - - - - - - - - - -	(17·1 and 17·2)		(2)

* Some of the estimations of ammoniacal, albuminoid, and total nitrogen were not quite satisfactory here, but they may be taken as substantially correct.

† The "3 minutes'" test in the earlier samples.

If the average figures for total nitrogen and for "oxygen absorbed" from permanganate in four hours, given by these chance samples, are compared with the corresponding figures of the hourly sets, it is seen that the chance samples are much the stronger. The figures for total nitrogen in six of them only varied between 9·9 and 12·8 parts. The dry-weather sewage, therefore, which the Ducat filter at Hendon has to treat during the hours of the day when it is most concentrated, is a very strong domestic sewage containing some laundry refuse; and although, on the average, the suspended matter over the whole twenty-four hours of the day is only about 20 parts per 100,000, it may at times rise to a high figure. Thus, in No. 727, drawn on Monday, October 10th, 1904, at 11·55 a.m., in dry weather, the suspended solids amounted to 55·2 parts, of which 12·7 were mineral; and in No. 544, drawn on Thursday, June 4th, 1903, at 1·30 p.m., the centrifuge figure indicated an equally large quantity. These solids, moreover, are not always well broken up as they pass on to the filter.

A portion of the chance sewage sample, No. 5, which was drawn on May 2nd, 1899, was filtered that day through a Pasteur-candle filter, the filtrate kept over-night in a full bottle, and the total nitrogen in it estimated next day. The comparative figures are interesting:—

Analysed	Original Sample, May 2nd.	Pasteur-filtered Sample, May 3rd.
Ammoniacal Nitrogen	6·35	
Albuminoid Nitrogen	1·55	
Total Organic Nitrogen	3·48	
Nitrous Nitrogen	0·04	
Total Nitrogen	9·87	7·45

So far, therefore, as this one experiment goes, it indicates that about 1·0 part per 100,000, out of 3·5 parts of organic nitrogen, was present in crystalloid form.

Bacteriological Notes.—The bacteriological results are given in Appendix C.

The Filters.

Number	2.
Size of each	15 feet by 12 feet.
Area of each	20 square yards.
Total area	40 square yards.
Depth of material	No. 1 filter, 8 feet. No. 2 filter, 10 feet.
Cubic content of each	No. 1 filter, 53·4 cube yards. No. 2 filter, 66·7 cube yards.
Total cubic content	120·1 cube yards.
Material	Furnace clinker varying from ¾ inch to ½ inch in diameter.

Construction.—On the concrete bottom (which in the case of No. 1 filter slopes four ways, while in No. 2 filter it only slopes three ways) four small square tunnels are built in a transverse direction. These through tunnels, which are constructed of perforated bricks at the sides and cemented pan tiles at the top, hot water pipes are carried. The tunnels communicate with the outer air, and are intended for the purpose of supplying air (artificially heated, if necessary) to the lower part of the filter. Between the tunnels a free bottom is constructed by means of roofing tiles, resting upon dwarf brick piers. The filtering material therefore rests partly on the false bottom and partly on the four tunnels.

In No. 1 filter it is carried up to a height of 8 feet, and in No. 2 to a height of 10 feet, being kept in position in both cases by walls of 4-inch agricultural pipes, laid horizontally, with a slight dip towards the material. These pipes are 12 inches long, and are cemented together. They are supported by brick piers at the four corners of the beds and also at the centres of the two sides.

Additional 4-inch porous pipes, two feet apart in a horizontal direction, are carried right through the material for the purpose of giving further aeration. In No. 1 filter the first layer is 4 feet 6 inches and the second 6 feet 6 inches from the bottom, while in No. 2 filter the first is 3 feet 6 inches, the second 5 feet 6 inches, and the third 8 feet from the bottom. There are therefore in No. 1 filter twelve lines of those pipes, and in No. 2 filter eighteen lines.

No. 1 filter is bolted together with wood. No. 2 filter is strapped with iron bands.

Both filters are completely enclosed in small buildings with thatched roofs, and are fitted at the sides with slow combustion stoves, for heating purposes in cold weather.

Distribution.—The distribution on to each filter is effected by means of twelve cast-iron tipping troughs, supported on the surface of the material by wooden blocks. The troughs are fed continuously from small slots cut in the delivery channel, which is carried along one side of each filter. When full of sewage, these troughs overbalance their counterweights, and discharge their contents on to the material at one side of the trough. The troughs need some attention, for they occasionally do not tip; but, on the whole, the distribution obtained is good.

Underdraining.—The false bottom, constructed between the tunnels, serves as the underdrain. The floor of No. 1 filter slopes four ways, and the filter effluent, which therefore runs out on the four sides is picked up by a channel carried round the filter on the inside of the building, being brought by this means to one point.

In the case of No. 2 filter the floor slopes only three ways, and a similar channel collects the effluent at three sides of the filter.

Working.—The filters work continuously, day and night. They have done so from the latter part of 1899, when the present material was placed in position.

In the beginning of 1905 the working of No. 1 filter was altered, for the purpose of some special experiments which were in contemplation at that time; but No. 2 filter still (1906) continues to work on the original plan.

The surfaces of the filters have been raked when necessary, but nothing has been removed. Three rakings in a year have been sufficient up to the present time.

Heating.—During cold weather both filters have been heated artificially by means of the water pipes carried through the tunnels. The plan adopted has been to commence heating during cold weather and to discontinue directly the weather became sufficiently warm.

Age of the Filters.—No. 1 filter in its present form was started on August 16th, 1899. No. 2 filter was brought into use on November 1st, 1899.

Unsettled Effluents.—Three sets of hourly samples and seventeen chance samples were examined chemically. The hourly sets, Nos. 601, 603 and 606, were drawn at the same time as the hourly samples of sewage, *i.e.*, September 14th to 17th, 1903, in dry weather. Each set was made up of twenty-four samples, taken in equal quantities every hour from filter No. 1, which had at this time been in use for four years.

They gave the following figures on analysis :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(0·81 to 1·36)	1·06	(3)
Albuminoid Nitrogen	(0·27 to 0·29)	0·28 †	(3)
Total Organic Nitrogen	-	(?)	
{Oxidized Nitrogen	(2·21 to 2·60)	2·37	(3)
{Containing Nitrous Nitrogen	(0·11 to 0·16)	0·14	(3)
Total Nitrogen	(3·28 to 3·88)	3·57	(3)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(0·63 to 0·97)	0·80	(3)
" " " " *in 4 hours*	(2·34 to 3·01)	2·65	(3)
Incubator test (Scudder)		2+,1-(slightly)	(3)
" " (by smell)		3 +	(3)
Smell when drawn		2 +, 1 –	(3)
Smell when analysed		3+	(3)
Chlorine	(7.90 to 8·20)	8·10	(3)
{Solids in suspension	(6.10 to 6·50)	6·33	(3)
{Containing mineral matter	(2·30 to 2·90)	2·57	(3)
Solids by Centrifuge (vols.)	(74·0 to 87·0)	81·0	(3)
Ratio of Solids in suspension to Centrifuge Solids	(1 : 11·6 to 1 : 13·6)	1 : 12·8	(3)

These hourly sets of effluent were very uniform in composition throughout. The liquid of the effluents was clear and of a faint yellowish tint, but the samples all contained considerable quantities of very flocculent brown matter in suspension. These solids pass out of the filter unequally, and the above samples happened to be drawn at a time when rather large quantities were being washed out. One of the effluents was noted as having a slight smell of sewage, but the other two had a clean smell when drawn, and all of them a clean smell when analysed, while they all readily withstood incubation. It will be seen that two-thirds of the nitrogen was present in them in the state of nitrate, but they also contained appreciable quantities of nitrite, especially after incubation, a sign that the oxidation had not reached its limit. This was, of course, mainly because of the suspended solids, which averaged fully six parts per 100,000, and therefore required to be settled out; but apart from this the effluents were of good quality.

Contrasted with the hourly samples of sewage (with which they are comparable) we find the following reduction in figures :—

Calculated on :—	Per cent.	Estimations.
Total Nitrogen	about 47	(2)
Ammoniacal Nitrogen	" 78	(3)
Albuminoid Nitrogen	" 77	(3)
"Oxygen absorbed" *at once*	" 68	(3)
" " *in 4 hours*	" 77	(3)
Solids in suspension	" 69	(3)
Mineral matter of solids	" 45	(3)

It is interesting to notice here that the *loss* of nitrogen amounted to 40 to 50 per cent. Another interesting point of those analyses is that the mineral matter of the suspended solids coming out of the filter averaged 2·6 parts, as against 4·7 parts going on in the suspended matter of the sewage. Any generalisation upon this point could only be made after a long series of estimations, but at the time in question there was some deposition of mineral matter in the filter.

† This figure is probably a little too high.

Chance Samples:—The seventeen chance samples of effluent examined chemically may with advantage be divided into two sets, A and B. Set A comprises the seven effluents Nos. 2, 4*, 6*a*, 8*, 10, 11 and 451, the first five of which were drawn between December 1898 and May 1899, and the last two in July, 1900, and January 1902. Four of them were drawn at 12 noon and the others at 2, 3, and 4 p.m. Without having actual notes on the point, we are practically certain that they were all drawn from filter No. 1, the 8-foot filter. All these samples, excepting No. 8, were drawn in dry weather.

The following figures were obtained :—

	Parts per 100,000.	Average.	Number of Estimations.
Series A.			
Ammoniacal Nitrogen	(0·05 to 0·82)	0·26	(7)
Albuminoid Nitrogen	(0·05 to 0·36)	0·12	(7)
{Oxidized Nitrogen	(3·91 to 6·56)	5·75	(7)
{Containing Nitrous Nitrogen	(0·0 to 0·06)	0·02	(7)
Total Nitrogen	(7·11 and 6·37)		(2)
"Oxygen absorbed" at 27° C. (80° F.) *in 3 minutes*†	(0·14 to 0·44)	0·28	(6)
" " " " *in 4 hours*	(0·73 to 1·14)	0·96	(7)
Smell when analysed		5+	(5)
c.c per litre :—			
Oxygen in solution	(4·0 ap. to 6·7)	5·8	(6)

The samples of series A were all bright or very slightly opalescent and almost colourless, with only traces, or little more than traces, of matter in suspension. All of them had a perfectly clean smell when analysed.‡ A glance at the above figures of analysis is sufficient to show the very high quality of these effluents, almost all their nitrogen being present in the state of nitrate (5·75 parts of nitric nitrogen on the average), with practically no nitrite. No 451, drawn in January, 1902, contained about 1 part of suspended solids, judging from the centrifuge figure, but up to that date apparently very little suspended matter at all had made its way through the filter.

A duplicate sample of No. 11, drawn on July 17th, 1900, which was mercury-jointed, had not exhausted all its dissolved oxygen by November 26th, *i.e.* it had only taken up about 0·8 part of oxygen (or about 6 c.c. per litre) in four months' time. The high quality of the Ducat filter effluents, therefore, in the first year of the life of the filter, was very remarkable, and this may be said to have continued for two or three years.

Four of the samples of Series A were boiled out for their dissolved gases, and were found to contain :—

C.C. of Gas per ~~litre~~ at N.T.P.	No. 4.	No. 6a.	No. 8.	No. 10.
Free Carbon Dioxide	—	3·9	3·7	—
Free and combined Carbon Dioxide	38·2	—	—	31·5
Oxygen	6·3	6·1	6·0	6·7
Nitrogen	13·9	13·3	13·8	15·1

Apart from the good oxygenation of the above samples, the figures are interesting as showing that so little free carbonic acid was left in solution in the effluent, the carbonic acid resulting from the oxidation of the organic matter having apparently been disengaged in the downward passage of the liquid through the filter, a result to be attributed to good aeration.

* The siphoned liquid of these two samples was taken for analysis.
† *At once*, in the case of No. 451.
‡ Not noted in two cases, but it may be taken as certain.

Series B.—The ten chance samples of unsettled effluent comprising Series B were Nos. 515, 545, 3314, 3315, 3416, 671, 672, "x," 703, and 728. They were drawn between April, 1903, and October, 1904, for the most part in the spring and autumn months, between the hours of 6.30 a.m. and 5.30 p.m., but nearly all of them about mid-day or in the early afternoon. They probably represent, therefore, a tolerably good average of the day samples during those years. About three-fourths of the samples were drawn in dry weather.

Six of the samples were drawn from No. 1 filter and two from No. 2 filter, while the remaining two samples were mixtures of effluent from both filters. The effluents from the two filters did not differ materially, excepting, perhaps, that those from No. 2 contained rather more suspended matter. They are therefore grouped together here.

They gave the following figures :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(0·08 to 1·20)	0·57	(8)
Albuminoid Nitrogen	(0·05 to 0·20)	0·13	(7)
Total Organic Nitrogen	(0·33 to 0·48 ?)	0·42	(5)
Oxidized Nitrogen	(2·40 ap. to 4·12)	3·51	(10)
Containing Nitrous Nitrogen	(0·0 to 0·07)	0·03	(10)
Total Nitrogen	(3·53 to 5·14 ap.)	4·48	(7)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(0·30 to 0·88)	0·51	(9)
" " " " " *in 4 hours*	(1·14 to 2·89)	1·87	(9)
Dissolved Oxygen taken up in 24 hours at 18°C.	(0·04 to 1·30)	0·62 ap.	(7)
Incubator test (Scudder)		8 +	(8)
Incubator test (by smell)		9 +	(9)
Smell when drawn		9 +	(9)
Smell when analysed		9 +	(9)
Chlorine	(6·84 to 9·10)	7·71	(4)
Solids in suspension	(0·50 to 14·90)	5·20	(8)
Solids by centrifuge (vols.)	(5·0 to 142·0)	53·7	(10)
Ratio of solids in suspension to centrifuge solids	(1 : 9·1 to 1 : 12·8)	1 : 10·5	(8)
c.c. per litre :—			
Oxygen in solution, when analysed	(1·35 ap. to 6·2)	3·9	(6)

The above effluents were of the same type as those already described; that is to say, the liquid portion was clear, or nearly clear, and bright, with a slight brownish tint, but—especially as time went on—the quantity of granular flocculent solids increased, the last sample examined (No. 728, drawn in October, 1904) containing as much as 14·9 parts. The average for the whole ten samples was 5·2 parts, hence the effluents latterly required settlement.

They all had a clean smell, both when drawn and when analysed, and all readily withstood incubation.

Some of them took up rather considerable quantities of dissolved oxygen in 24 hours, especially No. 728, but this was due to the suspended matter. Apart from this suspended matter, they were of very good quality.

On the average, the effluents of Series B. stood about midway in quality between the early chance samples of Series A., which were of exceptionally high class, and the hourly samples. With the continued use of such a fine-grained filter treating a rather strong laundry sewage containing about 20 parts of suspended solids, there must necessarily be a tendency for incompletely oxidized organic matter to go on accumulating in the small interstices of the filtering material. And, assuming aeration to continue perfect, and nitrification to go on as actively as ever, this organic matter will use up some of the nitrate

formed from the liquid of the sewage. The result will be an effluent less rich in nitrate, and also containing less total nitrogen. This is broadly shown, we think, from the average figures of the various analyses, thus:

Parts per 100,000.	Nitrous and Nitric Nitrogen.	Total Nitrogen.
Effluents, Series A.	5·8	6·5 ap. (inferred)
„ Series B.	3·5	4·5
„ Hourly Samples	2·5	3·6

Another possible explanation, on the assumption that, with partial clogging of the filter, aeration became less perfect (though our present evidence is against this), would be that less of the nitrogen reached the final stage of nitrate and that more nitrite was decomposed as the filter became older.

In fact, as time goes on, such a filter must be called upon to treat an augmenting quantity of organic impurity, unless an equilibrum ultimately establishes itself between the suspended colloidal and organic matter going on to the filter and that coming out of it.

Several of the effluents of Series B. were analysed in duplicate, both before and after filtration through paper, in order to ascertain to what extent the figures of analysis were affected by the suspended solids present. The following *average* figures were in this way obtained from Nos. 3314, 3315, 3416, 671, "x" and 703.

	Original Effluent.	After filtration through paper.	Number of Estimations.
Albuminoid Nitrogen	0·12	0·06	(5)
"Oxygen absorbed" at 27° C. *at once*	0·52	0·30	(5)
„ „ „ „ *in 4 hours*	1·88	1·07	(5)
Dissolved Oxygen taken up at 18° C. *in 24 hours*	0·76	0·13	(4)
Solids in Suspension	4·49		(5)
Solids by Centrifuge (vols.)	45·40		(5)

These figures require practically no comment. They show the excellent quality of the liquid portion of the Hendon Ducat filter effluent.

One or two figures may also be given at this point, showing the quantities of dissolved oxygen taken up by two of the effluents under different conditions of time and temperature:

——	Effluent No. 545.
Oxygen taken up in 24 hours at 18° C.	0·04
„ „ 6 hours at 27° C.	0·0
„ „ 4 hours at 37° C.	0·04
Solids in suspension	about 1·0 { from Centrifuge figure.

——	Effluent No. X. Original.	Filtered through paper.
Oxygen taken up in 24 hours at about 18° C.*	0.33	0·14
„ „ 48 „ „	0·57	0·20
„ „ 96 „ „	0·75	0·33
Solids in suspension	7·70	

The first of these effluents showed too little absorption to allow of any comparison of figures. In the case of No. "*x*," it will be noted that the absorption during the first day

*The temperature of the incubator fell to 14° C. during the second night and to 13° during the fourth night of the experiment.

was greater than during the second, and so on; this gradually decreasing absorption by the carbonaceous matter present may, as a general rule, we think, be taken as characteristic of well purified effluents as a whole.

Filtration of Sewage and of Effluent through a Pasteur-Chamberland Filter.—A few of the earlier samples of effluent were filtered through a Pasteur-Chamberland candle, but the effluents examined were already for the most part so pure that the results were indeterminate, the errors of analysis being relatively too great. It is well known that a sterile sewage or effluent may be kept for an indefinite time without undergoing any but the slightest direct oxidation by atmospheric oxygen.

The following simple experiment, made with one of the highly nitrated Ducat filter effluents in July, 1899, is of some interest.

To a portion of the siphoned effluent, there was added on July 18th, about 0·1 per cent. of cane sugar, the mixture being left in a bottle only partly full.

On July 21st the solution was cloudy with white flocculent matter, and it had a slight putrefactive odour.

On July 26th it showed an abundant growth, had an odour of cheese, and contained no nitrite.

On September 5th it had a strong smell of sulphuretted hydrogen.

On September 12th it was analysed, with the following result. Alongside are placed the figures given by a portion of the original siphoned effluent, as analysed on September 8th.

——	Original Effluent.	Effluent to which sugar had been added.
Ammoniacal Nitrogen	0·05	1·19
Albuminoid Nitrogen	0·07	0·79
Total Organic Nitrogen	0·17	1·79
Nitrous Nitrogen	0·0	—
Nitric Nitrogen	6·79	—
Total Nitrogen	7·04	3·09

The above experiment illustrates very clearly how, under favourable conditions, organic growths can be produced by the addition to a highly nitrated and well purified (but not sterile) effluent of a solution containing carbonaceous organic matter, not in itself offensive.

Solids deposited in Effluent Channel.—On September 17th, 1903, a sample of the deposited sediment was collected from the effluent channel of No. 2 filter. On reaching the laboratory it was dried by evaporation on the water bath and the residue was then powdered up for analysis, with the following results :—

——		Calculated on the dry material.
Moisture	10·12 per cent.	—
*Volatile Matter	43·80 „ „	†48·7 per cent.
Non Volatile	46·08 „ „	51·3 „ „
*Containing Nitrogen	3·08 „ „	†3·43 „ „

The sludge was then comparatively rich in nitrogenous matter. It consisted mainly of dark brown flocculent solids.

Absorption of Dissolved Oxygen and Nitrate.—Between May 12th and 16th, 1904, an experiment was made with the object of determining whether, upon incubation of an effluent, all the dissolved oxygen present is taken up before the nitrite and nitrate are

attacked, or whether both are absorbed simultaneously. For this purpose a mixed sample of effluent from filter No. 1, drawn May 11th, 1904, at 1.50 p.m., and from filter No. 2, drawn May 11th, 1904, at 2 p.m., was taken. The two Winchester quarts of these samples were mixed and the mixture again divided into two halves, one of which was filtered through paper.

They gave the following analyses :—

Parts per 100,000.	Original.	Paper filtered
Ammoniacal Nitrogen	0·67	0·71
Albuminoid Nitrogen	0·20	0·07
Total Organic Nitrogen	0·44	0·09
Nitrous Nitrogen	0·03	0·03
Nitric Nitrogen	4·09	4·09*
Total Nitrogen	5·23	4·92
"Oxygen absorbed" at 27° C. (80° F.) *at once*	0·53	0·32
" " " " " *in 4 hours*	2·14	0·94
Incubator test (Scudder)	Not noted.	+
" " (by smell)	+	+
Solids in Suspension	7·7	—
Solids by centrifuge (vols.)	76·4	—
Dissolved Oxygen taken up in 24 hours at 14°–18° C.	0·33	0·14
c.c. *per litre* Oxygen in Solution	5·25	6·80

Portions of the above effluents were then incubated for one, two and four days, and determinations made each day of : (1) the dissolved oxygen and (2) the (nitrite and nitrate) remaining in solution, thus :—

———	Original Sample.		Paper filtered Sample.	
Parts per 100,000.	Nitrous and Nitric Nitrogen.	Dif.	Nitrous and Nitric Nitrogen.	Dif.
May 12th	4·12		4·12	
		0·17		0·23
" 13th	3·95		3·89	
		0·03		0·06
" 14th	3·92		3·95	
		0·07		0·16
" 16th	3·85		3·79	
Total diminution of Oxidized Nitrogen in 4 days	—	0·27	—	0·33
Parts per 100,000.	Oxygen in Solution.	Dif.	Oxygen in Solution.	Dif.
May 12th	0·75		0·86	
		0·35		0·15
" 13th	0·40		0·71	
		0·22		0·05
" 14th	0·18		0·66	
		0·18 + x†		0·13
" 16th	0·00		0·53	
Total absorption of dissolved Oxygen in 4 days	—	0·75 + x	—	0·33

* Nitrate was only determined on the original sample.
† The oxygen of this incubated sample was exhausted.

Or, c.c. per litre.	Oxygen in Solution.	Dif.	Oxygen in Solution.	Dif.
May 12th - - - -	5·25	2·45	6·00	1·00
,, 13th - - - -	2·80	1·50	5·00	0·40
,, 14th - - - -	1·30	1·30 + x	4·60	0·90
,, 16th - - - -	0·0		3·70	
	—	5·25 + x	—	2·30

The raising of the temperature of the liquids in the foregoing experiment, from that of the laboratory in May (say, about 13° C.) to 27° C., the temperature of incubation, would only increase the volume of the liquid by 0·3 per cent., so that any error introduced by it would be negligible.

The above results are not conclusive, though they leave little doubt that, at all events in an effluent containing suspended matter, the dissolved oxygen is used up more rapidly than the nitrate, and is therefore a more readily available oxidising agent under such conditions. This is what one naturally expects on theoretical grounds, and it bears out the results of experiments made on very dilute liquids by Dr. Adeney.*

Analysis of Ducat Filter Gases.—With a view of testing the actual degree of æration of the No. 1 Ducat filter, gas was drawn at different times from various points in the interior of the filter, by hammering into the clinker, horizontally, a piece of ordinary iron gas tubing, the far end of which was closed temporarily by a cork or a flat-headed nail. (If this precaution is not taken, the tube becomes tightly stopped with small fragments of clinker, which it is almost impossible afterwards to dislodge. Another necessary precaution is not to hammer the end of the tube itself, but to interpose a piece of wood. The resistance of the tightly packed fine filtering material to the entrance of the tube is very considerable, and direct hammering distorts the circular bore, and may even crack the tube.)

When the tube had been inserted to the required distance, the cork or nail at the far end was knocked out by means of a long iron rod. The projecting end of the iron tube was now connected by suitable rubber and glass tubing with an aspirating bottle, filled with water or clear effluent, and after it had been sufficiently "washed out" in this way with the filter gas, samples of the gas were drawn into suitable collecting bottles. (The glass tubes in those bottles should be so arranged that practically no water is left in the bottle along with the gases, otherwise a disproportionate amount of carbonic acid, if present, will be dissolved.) When the gases of Series 3 and 4 were drawn, some clay was plastered round the iron tube at the spot where it emerged from the filter, as an additional safeguard against any air finding its way into the interior of the filter along the outside of the tube, when the aspirator was set in motion.

(When inserting the iron tube, care must be taken to keep it as far away as possible from the nearest of the ærating pipes which cross the filter from side to side.)

The results of the examinations were as follows :—

Series 1.—Drawn from No. 1 filter on Tuesday, March 21st, 1899, beginning 11.30 a.m. There had been 13° F. of frost during the preceding night.

———	S. side of Filter: 3 Feet from outside, and about half way between top and bottom.		S. side of Filter: 6 Feet from outside, *i.e.*, practically in the middle of the Filter.		Composition of Atmospheric Air.
Gases at N.T.P. Per cent. by Vol.	(*a*)	(*b*)	(*a*)	(*b*)	
Carbon Dioxide - - - - -	0·44†	0·40	0·67	—	Trace
Oxygen - - - - -	20·44	20·63	19·42	—	20·9
Nitrogen - - - - -	79·12	79·87	79·91	79·75	79·1

* See Fifth Report of Commission : Appendix VI, page 49.

† There was an appreciable amount of water (10 to 15 c.c.) left in the sample bottle, which had a capacity of about 300 c.c.

Series 2.—The gases of this series were drawn on Tuesday, May 2nd, 1899, from points in the filter very near to those of Series 1.

——	S. side of Filter, 3 feet from outside, and about half-way between top and bottom.			S. side of Filter, 6 feet from outside, *i.e.*, practically from the middle of the filter.		
Gases at N.T.P. Per cent. by vol.	(*a*)	(*b*)	Mean.	(*a*)	(*b*)	Mean.
Carbon Dioxide - - - - -	0·36	0·13	0·25	0·05	Tr.	0·03
Oxygen - - - - - -	20·02	20·27	20·14	20·62	20·22	20·42
Nitrogen - - - - - -	79·62	79·61	79·61	79·33	79·78	79·55

On both the above occasions, therefore, the gases in the interior of the filter were to all intents and purposes atmospheric air. At this time the filter was yielding a highly oxidised effluent, with nearly all its nitrogen in the form of nitrate.

In October, 1904, General Ducat allowed us to experiment upon the effect of closing up the ends of the "wall" pipes and of the "through" pipes with clay. Owing to pressure of other work this experiment was interrupted, and we are not in a position to report upon it. It is merely mentioned now, in order that the figures of analysis of some further samples of filter gases may be given.

Series 3.—The gases of this series were drawn on Friday, November 18th, 1904, at a time when (during the above experiment) the filter had become badly ponded all over the top, and a considerable quantity of untreated sewage was getting into the effluent channel by pouring over the top of the filter; the effluent, however, still showed two parts of nitric nitrogen.

———	A From W. side of Filter, 6 feet from outside, *i.e.*, as nearly as possible from the middle of the filter.	B From S. side of Filter, near the middle longitudinally, 4 feet from outside, and 4 feet 9 inches above the lowest layer of the actual filtering material.	C From W. side of Filter, near the middle longitudinally, but only 15 inches above the lowest layer of filtering material.
Gases at N.T.P. Per cent. by vol.	——	——	——
Carbon Dioxide - - - -	0·29	0·02	0·04
Oxygen - - - - - -	20·67	20·64	20·29
Nitrogen - - - - -	79·04	79·34	79·59

Here, again, the gases were practically atmospheric air. We have not yet sufficient knowledge to comment on the above, beyond pointing out that the filter may be badly ponded on the surface and may yet remain well aerated at the middle, and near the bottom; unfortunately no samples were drawn from near the top of the filter on this occasion.*

* *Note.*—Precisely similar results were obtained in some experiments relating to the filter gases in a large Ducat filter at Leeds. As they bear upon this point, it has been thought advisable to include them here.

A complete experimental installation of the Ducat process, constructed at the Leeds sewage works during the year 1899, gave results which form an instructive part of the long series of experiments carried out at these works by Colonel T. W. Harding and Mr. W. H. Harrison between the years 1898 and 1905.

Its history is given in the Report upon this work issued in June, 1905, under the section of "Crude Sewage Experiments on Percolating Filters," page 94 (Report on experiments in sewage disposal by Colonel T. W. Harding and W. H. Harrison, M.Sc., City of Leeds, June, 1905).

Briefly stated, it is a record of periodical surface clogging, resulting from the retention of the very fibrous suspended matter of the Leeds sewage on the surface of the fine clinker used as the filtering medium. First, the treatment of the Leeds crude sewage was tried, and afterwards the treatment of the liquor from the open septic tank.

With crude sewage the filter became clogged on the surface within one or two months, while with septic tank liquor it lasted from two to three years, with occasional raking and resting.

The filter was under observation for the Commission throughout the greater part of these experiments, and it was during the fourth and fifth trials with screened sewage that the present observations upon the composition of the air in the interior of the filter were made.

In the fifth experiment the filter was started on October 18th, 1900, after the clogged surface material resulting from the previous experiments had been removed and the filter itself given a rest of fourteen days.

The filter is 24 feet long, by 18 feet wide, by 10 feet deep.

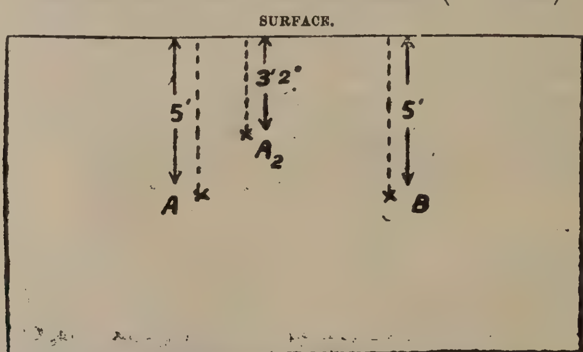
The rate of filtration was 52 gallons per cube yard per 24 hours.

The working of the filter is well seen in the following estimations of Dissolved Oxygen and Nitric Nitrogen, made upon samples of the filter effluent taken from time to time :—

Date.	Dissolved Oxygen, in c.c. per litre.	Nitric Nitrogen, in parts per 100,000.	Remarks.
October 18th - -			Filter started.
„ 20th - -	6·0	2·4	
„ 23rd - -	6·0	1·5	
„ 26th - -	7·0	1·35	
November 2nd - -	6·0	1·1	
„ 8th - -	6·0	1·25	
„ 9th - -	6·0	1·1	
„ 12th - -	6·0	1·28	
„ 16th - -	6·0		The effluent began to fall off on this day, and a grey growth made its appearance in the effluent chamber.
„ 20th - -	4·0 (approx)		Effluent much deteriorated in appearance.
„ 23rd - -	5·0	0·85	Bed ponding in various places.
„ 27th - -	4·0	1·0	The bed was rested all day on November 27th because of a flood. It recovered considerably as a result of this rest, and the ponding decreased to some extent.
December 1st - -	3·0	0·22	Ponding much increased.
„ 3rd - -	None	0.24	Bed under water.
„ 4th - -	„	0·24	„ „
„ 6th - -	„	0·40	„ „
„ 7th - -	„	0·5	„ „
„ 10th - -	„	0·26	„ „
„ 13th - -	„	0·14	„ „
„ 18th - -	„	0·19	„ „

The samples of air from the interior of the filter were drawn from the positions marked A, A_2 and B on the cross-section diagram below :—

Section of Ducat Bed at Leeds (to scale).



Note.—The pipes through which the gases were extracted were placed in the exact centre of the bed, lengthways.

Sample No. 1 was drawn at A, on November 20th, 4 p.m., shortly after ponding had commenced on the surface of the filter. Its composition was as follows :—

	Gases at N.T.P. Per cent. by Volume.
Carbon dioxide - - - - - - - - - -	0·35*
Oxygen - - - - - - - - - - -	20·25
Nitrogen - - - - - - - - - - -	79·40
	100·00

* Corrected for 0·08 of Carbon Dioxide in the 38 c.c. of water left in the gas sample bottle.

Sample No. 2 was also drawn at A, on November 27th, 4.50 p.m., when the surface of the filter was considerably ponded. No sewage was going on to the filter at this time. The filter was therefore in the process of recovering itself slightly. The composition of this sample was as follows :—

Carbon Dioxide - - - - - - - - - -	0·02
Oxygen - - - - - - - - - - -	20·56
Nitrogen - - - - - - - - - - -	79·42
	100·00

On December 7th, 1900, when the ponding had increased to a depth of 4 inches over almost the whole of the bed, a third sample, No. 3, was drawn, again at A. This had the following composition :—

Carbon Dioxide	0·06*
Oxygen	20·61
Nitrogen	79·33
	100·00

*Corrected.

Sample No. 4 was drawn at B, on December 8th, 11.30 a.m. the surface of the filter being still 4 inches under the ponded sewage. It had the following composition :—

Carbon Dioxide	0·0
Oxygen	20·58
Nitrogen	79·42
	100·00

All four samples therefore consisted practically of air.

Since there was no dissolved oxygen in the filter effluent at the time the last three samples of gas were drawn, it was expected that the air in the interior of the filter would show signs of being depleted of oxygen to some extent, and as the results appeared for this reason difficult to explain, a second series of samples was drawn and analysed.

After a complete rest of thirty-six days (December 18th, 1900, to January 22nd, 1901, inclusive), during which time the clogged surface (about 1 inch deep) of the material was removed and replaced, the filter was again started on January 23rd, 1901. It again began to show signs of ponding after running for rather over a month, the effect of this on the filter effluent being tested by periodical estimations of Dissolved Oxygen and Nitric Nitrogen, as follows: —

Date.	Dissolved Oxygen, in c.c. per litre.	Nitric Nitrogen, in parts per 100.000	Remarks.
1901.			
January 25th			Filter started.
February 4th	6·0	2·10	
„ 6th	6·0	1·46	
„ 14th	6·0	0·88	
„ 20th	6·0	1·42	
„ 28th	6·0	1·28	The filter showed signs of ponding when this sample was taken.
March 13th	3·5	0·75	
„ 18th	4·5	1·0	
„ 27th	1·0	0·3	Surface of filter under water.
April 1st	Trace.	0·23	„ „

In this second series of gas samples, one sample, No. 5, was drawn from A_2 at 12 noon on February 19th, when the bed was working perfectly well and when no signs of ponding were apparent. Its percentage composition was :—

Carbon Dioxide	1·24
Oxygen	19·10
Nitrogen	79·66
	100·00

Shortly after this the filter began to pond badly, and on March 29th, when the surface was again under water, the second sample of the series, No. 6, was drawn from B at 2.30 p.m. Its percentage composition was :—

Carbon Dioxide	0·34
Oxygen	20·43
Nitrogen	79·23
	100·00

The last two samples were drawn on April 1st, 1901, No. 7, from A_2 at 12.15 noon, and No. 8 from B at 12.45 noon, the filter being still completely ponded. Their composition was as follows :—

———	No. 7.	No. 8.
Carbon Dioxide	0·94	0·65
Oxygen	19·77	20·63
Nitrogen	79.29	78·72
	100·00	100·00

The foregoing examination of filter gases from the Leeds Ducat filter showed that the filter continued, as at Hendon, well aerated all the time, at depths of 3 feet 2 inches, and 5 feet; but there are no records of gases drawn from nearer the surface. The only difference in the figures of analysis—and that a slight one—was the greater quantity of carbon dioxide present in the gases drawn when the filter was producing a good effluent.

Series 4.—The gases of series 4 were drawn on Wednesday, December 7th, 1904, after the filter had been at rest since November 23rd, *i.e.*, for two weeks subsequent to the ponding of the surface. The "through" pipes and the heating pipes had been re-opened since November 23rd. The sludge on the top of the filter was now in the condition of a thick paste, while under the tipping troughs the clinker was free from sludge.

—	A. From W. side of filter, 6 feet from outside (very near to where sample A of series 3 was taken).	B. From S. side of filter (close to where sample B. of series 3 was taken).	C. From W. side of filter (close to where sample C. of series 3 was taken).
Gases at N. T. P. Per cent. by Vol.			
Carbon Dioxide - - -	0·40	0·32	0·00
Oxygen - - - -	20·04	20·92	20·63
Nitrogen - - - -	79·56	78·76	79·37

Again, these gases were practically atmospheric air.

Bacteriological Notes.—The bacteriological results are given in appendix C.

Amount of Sewage treated upon the Filters.—From gaugings of the total flow of filter effluent, made every half-hour for three consecutive days in September, 1903, we found that the total quantity of sewage being dealt with by the process was approximately 5,000 gallons per 24 hours. At this time, therefore, as each filter received half the total flow, the following quantities of crude sewage were being treated per day :—

No. 1 filter (8 feet deep) :

Per square yard per 24 hours - - - - - 125 gallons.
Per cube yard per 24 hours - - - - - - 46·5 „

No. 2 filter (10 feet deep) :

Per square yard per 24 hours - - - - - 125 gallons.
Per cube yard per 24 hours - - - - - - 37.4 „

When they were first brought into use, both filters received crude sewage at the rate of 175 gallons per square yard per 24 hours. The flow, therefore, has presumably become gradually less ; but the above amounts may be taken to be approximately correct for the period throughout which our later observations have been made.

Effect of Temperature on the Working of the Filters.—The temperature observations on the Ducat filters at Hendon have included measurements taken on the occasion of each visit to the installation, and also one set of measurements taken every few hours over a period of two days, in September, 1903. As the lowest effluent temperature measured in cold weather was 9° C. (48° F.), it may be safely inferred that the enclosing buildings and the artificial heating in winter months afford ample protection from the cold, and that there is therefore no danger of the filters being affected by frost. As a general rule, the effluent is slightly colder than the sewage, but at those times when the filter is warmed artificially, it is usually warmer than the sewage. The extreme differences noted were as follows :—

—	Sewage.	Effluent.
June 4th, 1903 - - - -	15°C. (59°F.)	13·3°C. (56°F.)
March 21st, 1899 - - -	9°C. (48°F.)	15°C. (59°F.)

SUMMARY.

The dry-weather high level sewage which is treated on the Ducat filter at Hendon is a domestic sewage of about average strength, containing some laundry refuse, but with only about 20 parts of suspended solids per 100,000. During the day hours, when it is most concentrated, it is a strong sewage, and it may also contain at times large quantities of suspended matter.

There is no grit settlement, the sewage being merely passed through a half-inch screen. On the other hand, this sewage does not represent a whole section of the high level sewage, being drawn at a point 4 inches above the bottom of the outfall sewer and also some distance below the surface of the liquid. The fact, also, of the withdrawal pipe being placed at right angles to the main flow must necessarily mean that the filter does not receive its full proportion of the larger suspended matter, a circumstance which must have an important bearing upon the working.

The main features of this filter are :—(1) The open sides and the aërating pipes which pass through the body of the filter ; (2) the fineness of the filtering material ($\frac{1}{2}$ inch to $\frac{3}{4}$ inch diameter), considered in reference to the *relatively* large quantity of suspended matter in the liquid treated ; (3) the provision against the sewage ever acquiring a low temperature in its passage through the filter, by enclosing the whole in a building with a thatched roof, and by an arrangement of hot-water pipes in the lower part of the filter.

Owing to the small size of the filtering medium, the undigested suspended matter of the sewage takes a long time to find its way through the filter. During the first two years or so of the working of the filters, the effluent contained very little matter in suspension, but after this the solids worked through in gradually increasing quantity. Assuming the rate of flow during the five years ending October, 1904,* to have averaged what we found in our measurements in September, 1903, then No. 1 filter treated during those years an average of 46·5 gallons of crude sewage per cube yard, per 24 hours ; and on the same basis, No. 2 filter treated during the six years ending December, 1905, an average of 37·4 gallons. We understand, however, that at the commencement the filters were treating an average of about 66 and 53 gallons per cube yard respectively. Although at the two dates mentioned above the upper layers of clinker contained a good deal of sludge, both beds were still working freely. We are not in a position, therefore, to offer any estimate as to the probable limit of "life" of such a filter.

We think that the main reasons why these fine-grained filters have been able to treat a liquid containing relatively so much suspended matter are :—(1) because the actual volume treated has not been large for a percolating filter ; (2) because the flow of sewage has not been subject to large fluctuations, from flushes of storm water ; and (3) because the good aëration and the protection from cold afforded by the covered building, and by the artificial heating during the winter months, have assisted towards the conversion of the undigestible suspended solids of the sewage into such a granular form that they ultimately find their way through the interstices of the filtering medium. That this matter does get through is evidenced by the figure of 6 to 7 parts of suspended solids in the hourly samples of effluent examined, while a chance sample, drawn from No. 1 filter in October, 1904, showed as much as 14·9 parts. The superintendent in charge of the installation informed us that he frequently noticed the beneficial effect of warming, in that it led to an increased quantity of solids issuing from the filter, and thereby relieved any local tendency to surface clogging.

The distribution given by the tipping troughs is on the whole good, but the small slits in the channel from which the tippers are fed are apt to become blocked, and they therefore require a good deal of attention. This defect must of course be more pronounced the smaller the installation. The troughs themselves also require to be looked after to some extent. The system has, however, the advantage that the distribution is on the whole maintained, even if one or two troughs do get out of order, and, further, that it is independent of fluctuations in the flow.

* At this time No. 1 filter began to be used for experimental purposes, *i.e.*, it was no longer worked normally.

The various effluents examined at intervals over about seven years have—apart from the suspended matter in the later samples—always been of good quality chemically, and every sample has withstood incubation. The earlier samples were of very high class indeed, but, as the solids began to work through the filter (showing that they were present in the body of the filter in some quantity), the effluents became less highly nitrated and required settlement. At the same time the liquid portion of the effluent has continued very well purified throughout. Bacteriologically, there can be no question that the Ducat process is capable of effecting, for a prolonged period, a remarkable reduction in the number of bacteria in the Hendon high-level crude sewage. About half of the samples examined, out of a large number, yielded a negative result with a ten-thousandth of a cubic centimetre with the B. coli test and presumptive tests for B. coli. The results, as judged by the B. enteritidis sporogenes test, were also good.

Outside the buildings which enclose the filters there is never any nuisance from smell, and the buildings themselves, with their thatched roofs, are not suggestive of sewage disposal works.

In concluding this report we would like to acknowledge the kindness and assistance always extended to us by the late Colonel Ducat. We are also much indebted to General Ducat, and to Mr. Alfred Choat, who was in charge of the installation during our observations.

ROYAL COMMISSION ON SEWAGE DISPOSAL.

APPENDIX C.

"DUCAT" FILTER PROCESS AT HENDON.

RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF:—

HENDON CRUDE SEWAGE (45 SAMPLES).
EFFLUENTS FROM DUCAT FILTERS, No. 1 AND No. 2 (128 SAMPLES).
EFFLUENTS FROM DUCAT FILTER AFTER SAND FILTRATION (52 SAMPLES).

CONTENTS.

GENERAL REMARKS.

ADDENDUM:—CONSIDERATION OF THE BACTERIOLOGICAL RESULTS IN RELATION TO PROVISIONAL STANDARDS (NON-DRINKING WATER STREAMS).

A. C. HOUSTON.

April 1905.

Results of the Bacteriolcgi

1						2		3						4		
Description of the Sample.						Total Number of Bacteria in 1 c.c.		Number of B. Coli (or closely allied forms) in 1 c.c.						Chief Biological Cha- ters of the *strain* Coli present in t number specified Col. 3.		
No.	Time of Collection.				Other Details.									Gas.	Indol.	(a) Ac (b) C (Litr milk tures, at 37
	Hour.	Day.	Month.	Year.		Gelatine at 20° C.	Agar at 37° C.	1	10	100	1,000	10,000	100,000	(Gelatine "shake" cultures, 24 hrs. at 20° C.)	(Broth cultures 5 days at 37° C.)	
								1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.			(a)
					Hendon Crude Sewage.											
1 ..		2	5	1899	Crude Sewage - - - - -	8,700,000	730,000						+	+	—	+
2 ..		16	5	1899	Crude Sewage - - - - -	11,500,000	2,640,000						+	+	+	+
3 ..		31	5	1899	Crude Sewage - - - - -	32,000,000	3,070,000					+		+	+	+
4 (419) ..		18	11	1901	Crude Sewage - - - - -	26,500,000	5,050,000						+	+	+	+
5 (421) ..		20	11	1901	Crude Sewage - - - - -											
6 (425) ..		26	11	1901	Crude Sewage - - - - -	46,400,000	3,480,000						+	+	+	+
7 (429) ..		28	11	1901	Crude Sewage - - - - -											
8 (433) ..		2	12	1901	Crude Sewage - - - - -	29,700,000	2,830,000						+	+	+	+
9 (437) ..		4	12	1901	Crude Sewage - - - -											
10 ..		10	12	1901	Crude Sewage - - - - -	27,100,000	4,690,000						+	+	+	+
11 ..			11	1902	Crude Sewage - - - -		1,920,000									
12 ..		12	11	1902	Crude Sewage - - - -		15,000,000									
13 ..		13	11	1902	Crude Sewage - - - -		14,000,000									
14 ..		14	11	1902	Crude Sewage - - - -		11,700,000									
15 ..		17	11	1902	Crude Sewage - - - -		4,000,000									
16 ..		18	11	1902	Crude Sewage - - - -		14,300,000									
17 ..		19	11	1902	Crude Sewage - - - -		5,300 000									
18 ..		20	11	1902	Crude Sewage - - - -		5,100 000									
19 ..		26	11	1902	Crude Sewage - - - -		14,300,000									
20 ..		27	11	1902	Crude Sewage - - - -		7,800,000									
21 ..		28	11	1902	Crude Sewage - - - -		8,300 000									
22 ..		1	12	1902	Crude Sewage - - - -		13,900,000									
23 ..		2	12	1902	Crude Sewage - - - -		12,400,000									
24 (544) ..		4	6	1903	Crude Sewage - - - -											
25 (76) ..	2.45 p.m.	28	7	1904	Crude Sewage - - - -											
26 (80) ..	2.30 p.m.	2	8	1904	Crude Sewage - - -											

...INATION OF HENDON CRUDE SEWAGE.

5				6						7						8						9	
"Gas" Test. ...' production in gelatine ...e" cultures, 24 hours at 20° C.				B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						In.=Indol Test. B.S.=Bile-salt glucose peptone test.						Neutral-red Broth Test. Greenish-yellow fluorescence, 48 hours at 37° C.						No.	REMARKS.
100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000		
·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.		
						+	—															1	
							+	—														2	
								+														3	B. pyocyaneus isolated from this sample.
			In. +				+	—					+	—							+	4 (419)	
								+	—					+	—						+	5 (421)	
			In. +				+	—					+	—							+	6 (425)	
							+	—					+	—							+	7 (429)	
			In. +				+	—					+	—							+	8 (433)	
								+	—				+	—							+	9 (437	
			In. +					+	—				+	—							+	10	
																						11	
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																						22	
																						23	
							+	—													+	24 (544)	
							+	—													+	25 (76)	
							+	—													+	26 (80)	

RESULTS OF THE BACTERIOLOGICAL EXAMINATI

1						2		3						4		
Description of the Sample.						Total Number of Bacteria in 1 c.c.		Number of B. Coli (or closely allied forms) in 1 c.c.						Chief Biological Chara ters of the *strain* of B Coli present in the number specified i Col. 3.		
No.	Time of Collection.				Other Details.	Gelatine at 20° C.	Agar at 37° C.	1	10	100	1,000	10,000	100,000	Gas.	Indol.	(a) Acidi (b) Clot (Litmus milk cu tures, 5 d at 37° C
	Hour.	Day.	Month.	Year.				1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	(Gelatine "shake" cultures, 24 hrs. at 20° C.)	(Broth cultures 5 days at 37° C.)	(a)
					HENDON CRUDE SEWAGE											
27 (85)	3.5 p.m.	3	8	1904	Crude Sewage - - - -											
28 (89)	1.45 p.m.	8	8	1904	Crude Sewage - - - -											
29 (102)	3.20 p.m.	9	8	1904	Crude Sewage - - - -											
30 (109)	2.40 p.m.	10	8	1904	Crude Sewage - - - -											
31 (117)	4.15 p.m.	11	8	1904	Crude Sewage - - - -											
32 (135)	3.10 p.m.	12	9	1904	Crude Sewage - - - -								+	+	+	+
33 (139)	3.16 p.m.	13	9	1904	Crude Sewage - - - -								+	+	+	+
34 (147)	3.20 p.m.	16	9	1904	Crude Sewage - - - -								+	+	+	+
35 (151)	3.5 p.m.	22	9	1904	Crude Sewage - - - -								+	+	+	+
36 (155)	3.12 p.m.	23	9	1904	Crude Sewage - - - -								+	+	+	+
37 (159)	3.24 p.m.	26	9	1904	Crude Sewage - - - -								+	+	+	+
38 (163)	3.28 p.m.	27	9	1904	Crude Sewage - - - -								+	+	–	+
39 (167)	3.22 p.m.	28	9	1904	Crude Sewage - - - -								+	+	+	+
40 (171)	3.42 p.m.	29	9	1904	Crude Sewage - - - -								+	+	–	+
41 (179)	3.17 p.m.	3	10	1904	Crude Sewage - - - -								+	+	+	+
42 (183)	3.48 p.m.	4	10	1904	Crude Sewage - - -								+	+	–	+
43 (187)	3.0 p.m.	5	10	1904	Crude Sewage - - - -								+	+	+	+
44 (194)	3.25 p.m.	6	10	1904	Crude Sewage - - - -								+	+	+	+
45 (200)	3.8 p.m.	7	10	1904	Crude Sewage - - - -								+	+	+	+
Averages						Gelatine at 20° C., 25,985,714 per c.c. Agar at 37° C., 7,525,500 per c.c.		20 samples at 100,000, 1 sample at 10,000 per c.c.						17 out of 21, indol clot. 2 out of 21 neither in nor clot. 2 out of 21 clot, bu indol.		

HENDON CRUDE SEWAGE—*Continued.*

5					6						7						8						9	
" Gas " Test. s " production in gelatine ,ke " cultures, 24 hours at 20° C.					B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's " enteritidis change " in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						In.=Indol Test. B.S.=Bile-salt glucose peptone test.						Neutral-red Broth Test. Greenish-yellow fluorescence, 48 hours at 37° C.						No.	REMARKS.
10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000		
1 .c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.		
							+	—														+	27 (85)	
								+	—													+	28 (89)	
									+													+	29 (102)	
							+	–														+	30 (109)	
							+	–														+	31 (117)	
				B.S. +				+	–													+	32 (135)	
				B.S. +				+	–													+	33 (139)	
				B.S. +				+	–													+	34 (147)	
				B.S. +				+	–													+	35 (151)	
				B.S. +			+	–														+	36 (155)	
				B.S. +					+													+	37 (159)	
				B.S. +				+	–													+	38 (163)	
				B.S. +				+	–													+	39 (167)	
				B.S. +				+	–													+	40 (171)	
				B.S. +				+	–													+	41 (179)	
				B.S. +					+													+	42 (183)	
				B.S. +			+	–														+	43 (187)	
				B.S. +				+	–													+	44 (194)	
				B.S. +				+	–													+	45 (200)	
l test: All 4 samples ,000 per c.c. salt glucose peptone t: All 14 samples ,000 per c.c.					7 samples 10,000 } 19 samples 1,000 } per c.c. 6 samples 100 }						With one exception the samples yielded positive results with ·001 c.c.						All 29 samples 100,000 per c.c.							

RESULTS OF THE BACTERIOLOGICAL EXAMINATI

1						2		3						4		
Description of the Sample.						Total Number of Bacteria in 1 c.c.		Number of B. Coli (or closely allied forms) in 1 c.c.						Chief Biological Ch ters of the *strain* Coli present in t number specified Col. 3.		
No.	Time of Collection.				Other Details.			1	10	100	1,000	10,000	100,000	Gas.	Indol.	(a) Ac (b) C (Litr milk tures, at 37
	Hour.	Day.	Month.	Year.		Gelatine at 20° C.	Agar at 37° C.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	(Gelatine "shake" cultures, 24 hrs. at 20° C.)	(Broth cultures 5 days at 37° C.)	(a)
1 ..	—	2	5	1899	Final Effluent, Ducat's Filter, Hendon.	76,000	25,000				+	—		+	+	+
2 ..	—	16	5	1899	Final Effluent, Ducat's Filter, Hen on.	50,000	36,000				+	—		+	—	+
3 ..	—	31	5	1899	Final Effluent, Ducat's Filter, Hendon.	87,000	77,000				+	—		+	+	+
4 ..	—	17	7	1900	Final Effluent, Ducat's Filter, Hendon.											
(418) ..	—	18	11	1901	Final Effluent, No. 2 Filter ..	1,368,000	182,400					+	—	+	+	+
6 (420) ..	—	18	11	1901	Final Effluent, No. 1 Filter ..	370 000	34,000					+	—			
7 (422) ..	—	20	11	1901	Final Effluent, No. 1 Filter ..											
8 (423) ..	—	20	11	1901	Final Effluent, No. 2 Filter ..											
9 (426) ..	—	26	11	1901	Final Effluent, No. 1 Filter ..	7,200,000	476,000						+	+	+	+
10 (427) ..	—	26	11	1901	Final Effluent, No. 2 Filter ..	3,650,000	132,000						+	+	+	+
11 (430) ..	—	28	11	1901	Final Effluent, No. 1 Filter ..											
12 (431) ..	—	28	11	1901	Final Effluent, No 2 Filter ..											
13 (434) ..	—	2	12	1901	Final Effluent, No. 1 Filter ..	7,600,000	280,000					+	—	+	+	
14 (435) ..	—	2	12	1901	Final Effluent, No. 2 Filter ..	550,000	70,000					+	—	+	+	+
15 (438) ..		4	12	1901	Final Effluent, No. 1 Filter ..											
16 (439) ..	—	4	12	1901	Final Effluent, No. 2 Filter ..											
..	—	10	12	1901	Final Effluent, No. 1 Filter ..	160,000	22,000					—				
18 ..	—	10	12	1901	Final Effluent, No. 2 Filter ..	120,000	24,000				+	—				
19 ..	—	11	11	1902	Final Effluent, No. 1 Filter ..		954 000									
20 ..	—	11	11	1902	Final Effluent, No. 2 Filter ..		7,040									
21 ..	—	12	11	1902	Final Effluent, No. 1 Filter ..		280,000									

THE HENDON DUCAT FILTER EFFLUENT—(*continued*).

5				6						7						8						9	
"Gas" Test. production in gelatine " cultures, 24 hours at 20° C.				B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						In.=Indol Test. B.S.=Bile-salt glucose peptone test.						Neutral-red Broth Test. Greenish-yellow fluorescence, 48 hours at 37° C.						No.	REMARKS.
100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000		
·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.		
				+	—																	1	
					+	—																2	
				+	—																	3	
				+	—																	4	
—					+	—								In. +	—					+		5	
—						+	—							In. +					+	—		6 (420)	
+	—					+	—														+	7 (422)	
+	—					+	—														+	8 (423)	
+	—					+	—								In +						+	9 (426)	Owing, however, to ponding on top of filter. this effluent was mixed with untreated sewage.
+	—				+	—									In. +					+	—	10 (427)	
—						+	—													+	—	11 (430)	
—						+	—													+	—	12 (431)	
+	—					+	—							In. +	—					+	—	13 (434)	
—					+	—								In. +	—					+	—	14 (435)	
+	—					+	—														+	15 (438)	
—					+	—													+	—		16 (439)	
—						+	—						In +	—					+	—		17	
—						+	—								In +					+	—	18	
																						19	
																						20	
																						21	

RESULTS OF THE BACTERIOLOGICAL EXAMINATION

1						2		3						4			
Description of the Sample.						Total Number of Bacteria in 1 c.c.		Number of B. Coli (or closely allied forms) in 1 c.c.						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection.				Other Details.	Gelatine at 20° C.	Agar at 37° C.	1	10	100	1,000	10,000	100,000	Gas.	Indol.	(a) Acidity (b) Clot (Litmus milk cultures, 5 days at 37° C.)	
	Hour.	Day.	Month.	Year.				1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	(Gelatine "shake" cultures, 24 hrs. at 20° C.)	(Broth cultures 5 days at 37° C.)	(a)	(
22 ..	—	12	11	1902	Final Effluent, No. 2 Filter ..	—	33,000										
23 ..	—	13	11	1902	Final Effluent, No. 1 Filter ..	—	174,000										
24 ..	—	13	11	1902	Final Effluent, No. 2 Filter ..	—	48,000										
25 ..	—	14	11	1902	Final Effluent, No. 1 Filter ..	—	1,500,000										
26 ..	—	14	11	1902	Final Effluent, No. 2 Filter ..	—	94,400										
27 ..	—	17	11	1902	Final Effluent, No. 2 Filter ..	—	450,000										
28 ..	—	18	11	1902	Final Effluent, No. 1 Filter ..		328,000										
29 ..	—	18	11	1902	Final Effluent, No. 2 Filter ..		246,000										
30 ..	—	19	11	1902	Final Effluent, No. 1 Filter ..		1,310,000										
31 ..	—	19	11	1902	Final Effluent, No. 2 Filter ..		272,000										
32 ..	—	20	11	1902	Final Effluent, No. 1 Filter ..		264,000										
33 ..	—	20	11	1902	Final Effluent, No. 2 Filter ..		48,800										
34 ..	—	26	11	1902	Final Effluent, No. 1 Filter ..		1,360,000										
35 ..	—	26	11	1902	Final Effluent, No. 2 Filter ..		41,200										
36 ..	—	27	11	1902	Final Effluent, No. 1 Filter ..		1,760,000										
37 ..	—	27	11	1902	Final Effluent, No. 2 Filter ..		26,000										
38 ..	—	28	11	1902	Final Effluent, No. 1 Filter ..		340,000										
39 ..	—	28	11	1902	Final Effluent, No. 2 Filter ..		46,000										
40 ..	—	1	12	1902	Final Effluent, No. 1 Filter ..		570,000										
41 ..	—	1	12	1902	Final Effluent, No. 2 Filter ..	—	169,000										
42 ..	—	2	12	1902	Final Effluent, No. 1 Filter ..	—	1,020,000										
43 ..	—	2	12	1902	Final Effluent, No. 2 Filter ..	—	364,000										
44 (515) ..	—	2	4	1903	Final Effluent, No 1 Filter (8 ft. deep).												

5					6						7						8						9	
"Gas" Test. " production in gelatine e" cultures, 24 hours at 20° C.					B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						In.=Indol Test. B.S.=Bile-salt glucose peptone test.						Neutral-red Broth Test. Greenish-yellow fluorescence, 48 hours at 37° C.						No.	REMARKS.
) c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.		
																							22	
																							23	
																							24	
																							25	
																							26	
																							27	
																							28	
																							29	
																							30	
																							31	
																							32	
																							33	
																							34	
																							35	
																							36	
																							37	
																							38	
																							39	
																							40	
																							41	
																							42	
																							43	
							+	—													+	—	44 (515)	

RESULTS OF THE BACTERIOLOGICAL EXAMINATIO

1						2		3						4		
Description of the Sample.						Total Number of Bacteria in 1 c.c.		Number of B. Coli (or closely allied forms) in 1 c.c.						Chief Biological Char ters of the *strain* of Coli present in th number specified Col. 3.		
No.	Time of Collection.				Other Details.									Gas.	Indol.	(a) Aci (b) Cl (Litm milk c tures, 5 at 37°
	Hour.	Day.	Month.	Year.		Gelatine at 20° C.	Agar at 37° C.	1	10	100	1,000	10,000	100,000	(Gelatine "shake" cultures, 24 hrs. at 20° C.)	(Broth cultures 5 days at 37° C.)	
								1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.			(a)
45 (545) ..	—	4	6	1903	Final Effluent, No. 1 Filter ..											
46 (601) ..	24 hours' average	15	9	1903	Final Effluent, No. 1 Filter ..							+	—	+	+	+
47 (603) ..	24 hours' average	16	9	1903	Final Effluent, No. 1 Filter ..						+	—		+	—	+
48 (606) ..	24 hours' average	17	9	1903	Final Effluent, (?) No. 1 Filter ..							+	—	+	+	+
49 (607) ..	—	17	9	1903	Sample of Sediment collected in Effluent Channel.								+	+	—	+
50 (3416)..	—	6	3	1904	Mixed Final Effluent, both beds						+	—		+	+	+
51 (671) ..	—	11	4	1904	Final Effluent, No. 2 Filter (10 ft. deep).					+	—			+	+	+
52 (672) ..	—	11	4	1904	Final Effluent, No. 1 Filter ..						+	—		+	+	+
53 (703) ..	—	7	6	1904	Final Effluent, No. 2 Filter ..							+	—	+	+	+
54 (77) ..	2.40 p.m.	28	7	1904	Final Effluent, No. 1 Filter ..											
55 (78) ..	2.40 p.m.	28	7	1904	Ducat Final Effluent, No. 2 Filter											
56 (81) ..	2.36 p.m.	1	8	1904	Ducat Final Effluent, No. 1 Filter											
57 (82) ..	2.48 p.m.	1	8	1904	Ducat Final Effluent, No. 2 Filter											
58 (86) ..	3.10 p.m.	3	8	1904	Ducat Final Effluent, No. 1 Filter											
59 (87) ..	3.27 p.m.	3	8	1904	Ducat Final Effluent, No. 2 Filter											
60 (90) ..	2.51 p.m.	8	8	1904	Ducat Final Effluent, No. 1 Filter											
61 (91) ..	3 p.m.	8	8	1904	Ducat Final Effluent, No. 2 Filter											
62 (103) ..	3.24 p.m.	9	8	1904	Ducat Final Effluent, No. 1 Filter											
63 (104) ..	3.37 p.m.	9	8	1904	Ducat Final Effluent, No. 2 Filter											
64 (110) ..	2.44 p.m.	10	8	1904	Ducat Final Effluent, No. 1 Filter											
65 (111) ..	2.53 p.m.	10	8	1904	Ducat Final Effluent, No. 2 Filter											
66 (118) ..	4.18 p.m.	11	8	1904	Ducat Final Effluent, No. 1 Filter											
67 (119) ..	4.28 p.m.	11	8	1904	Ducat Final Effluent, No. 2 Filter											

THE HENDON DUCAT FILTER EFFLUENT—(*continued*).

5				6						7						8						9	
"Gas" Test. production in gelatine " cultures, 24 hours at 20° C.				B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						In.=Indol Test. B.S.=Bile-salt glucose peptone test.						Neutral-red Broth Test. Greenish-yellow fluorescence, 48 hours at 37° C.						No.	REMARKS.
100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000		
·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	0001 c.c.	·00001 c.c.		
					+	—													+	—		45 (545)	
						+	—													+	—	46 (601)	
						+	—												+	—		47 (60[illegible])	
							+													+	—	48 (606)	
								+													+	49 (607)	
						+	—												+	—		50 (3416)	
						+	—											+	—			51 (671)	
						+	—												+	—		52 (672)	
					+	—														+	—	53 (703	
						+	—														+	54 (77)	
						+	—												+	—		55 (78)	
						+	—														+	56 (81)	
					+	—													+	—		57 (82)	
							+	—													+	58 (86)	
						+	—													+	—	59 (87)	
							+	—													+	60 (90)	Filters were stopped for the night of August 5th while the sewage carriers were cleaned.
				+	—															+	—	61 (9[illegible])	
							+	—													+	62 (103)	
					+	—														+	—	63 (104)	
						+	—												+	—		64 (110)	
							+	—												+	—	65 (111)	
								+													+	66 (118)	
					+	—														+	—	67 (119)	

RESULTS OF THE BACTERIOLOGICAL EXAMINATIO

1						2		3						4		
Description of the Sample.						Total Number of Bacteria in 1 c.c.		Number of B. Coli (or closely allied forms) in 1 c.c.						Chief Biological Characters of the *strain* o Coli present in th number specified Col. 3.		
No.	Time of Collection. Hour.	Day.	Month.	Year.	Other Details.	Gelatine at 20° C.	Agar at 37° C.	1 (1 c.c.)	10 (·1 c.c.)	100 (·01 c.c.)	1,000 (·001 c.c.)	10,000 (·0001 c.c.)	100,000 (·00001 c.c.)	Gas. (Gelatine "shake" cultures, 24 hrs. at 20° C.)	Indol. (Broth cultures 5 days at 37° C.)	(a) Aci (b) Cl (Litm milk tures, 5 at 37 (a)
68 (136) ..	3.15 p.m.	12	9	1904	Ducat Final Effluent, No. 1 Filter						+			+	+	+
69 (137) ..	3.18 p.m.	12	9	1904	Ducat Final Effluent, No. 2 Filter							+		+	—	+
70 (140) ..	3.20 p.m.	13	9	1904	Ducat Final Effluent, No. 1 Filter								+	+	+	+
71 (141) ..	3.30 p.m.	13	9	1904	Ducat Final Effluent, No. 2 Filter							+		+	+	Alk
72 (143) ..	3.13 p.m.	14	9	1904	Ducat Final Effluent, No. 1 Filter							—				
73 (144) ..	3.24 p.m.	14	9	1904	Ducat Final Effluent, No. 2 Filter							—				
74 (148) ..	3.23 p.m.	16	9	1904	Ducat Final Effluent, No. 1 Filter								+	+	+	+
75 (149) ..	3.33 p.m.	16	9	1904	Ducat Final Effluent, No. 2 Filter							+		+	+	+
76 (152) ..	3.10 p.m.	22	9	1904	Ducat Final Effluent, No. 1 Filter							+		+	+	+
77 (153) ..	3.20 p.m.	22	9	1904	Ducat Final Effluent, No. 2 Filter							—				
78 (156) ..	3.16 p.m.	23	9	1904	Ducat Final Effluent, No. 1 Filter								+	+	+	+
79 (157) ..	3.27 p.m.	23	9	1904	Ducat Final Effluent, No. 2 Filter						+			+	+	+
80 (160) ..	3.27 p.m.	26	9	1904	Ducat Final Effluent, No. 1 Filter							+		+	—	+
81 (161) ..	3.39 p.m.	26	9	1904	Ducat Final Effluent, No. 2 Filter						+			+	+	+
82 (164) ..	3.31 p.m.	27	9	1904	Ducat Final Effluent, No. 1 Filter							+		+	+	+
83 (165) ..	3.40 p.m.	27	9	1904	Ducat Final Effluent, No. 2 Filter						+			+	+	+
84 (169) ..	3.33 p.m.	28	9	1904	Ducat Final Effluent, No. 2 Filter							+		+	+	+
85 (172) ..	3.45 p.m.	29	9	1904	Ducat Final Effluent, No. 1 Filter								+	+	+	+
86 (173) ..	3.54 p.m.	29	9	1904	Ducat Final Effluent, No. 2 Filter								+	+	—	+
87 (176) ..	3.33 p.m.	30	9	1904	Ducat Final Effluent, No. 1 Filter							+		+	—	+
88 (177) ..	3.42 p.m.	30	9	1904	Ducat Final Effluent, No. 2 Filter							+		+	—	+
89 (180) ..	3.[illegible]0 p.m.	3	10	1904	Ducat Final Effluent, No. 1 Filter							+	—	+	+	+
90 (181) ..	3.33 p.m.	3	10	1904	Ducat Final Effluent, No. 2 Filter					+	—			+	+	+
91 (184) ..	3.52 p.m.	4	10	1904	Ducat Final Effluent, No. 1 Filter					+		+		+	+	+
92 (188) ..	3.3 p m	5	10	1904	Ducat Final Effluent, No. 1 Filter								+	+		+

THE HENDON DUCAT FILTER EFFLUENT—(*continued*).

5					6						7						8						9	
"Gas" Test. …" production in gelatine …ke" cultures, 24 hours at 20° C.					B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						In.=Indol Test. B.S.=Bile-salt glucose peptone test.						Neutral-red Broth Test. Greenish-yellow fluorescence, 48 hours at 37° C.						No.	REMARKS.
0	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000		
1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.		
							+	—						B.S. +	—					+	—		68 (136)	
							+	—							B.S. +	—					+	—	69 (137)	
							+	—								B.S. +						+	70 (140)	
							+	—							B.S. +	—					+	—	71 (141)	
								+	—						B.S. +	—						+	72 (143)	
							+	—							B.S. +	—					+	—	73 (144)	
								+	—						B.S. +	—						+	74 (148)	
							+	—							B.S. +	—					+	—	75 (149)	
								+	—						B.S. +	—						+	76 (152)	
								+							B.S. +	—					+	—	77 (153)	
							+	—								B.S. +					+	—	78 (156)	
						+	—							B.S. +	—					+	—		79 (157)	
							+	—							B.S. +	—					+	—	80 (160)	
							+	—						B.S. +	—					+	—		81 (161)	
								+	—						B.S. +	—					+	—	82 (164)	
							+	—						B.S. +	—					+	—		83 (165)	
							+	—							B.S. +	—				+	—		84 (169)	
								+	—							B.S. +					+	—	85 (172)	
							+	—								B.S. +					+	—	86 (173)	
							+	—							B.S. +	—					+	—	87 (176)	
						+	—								B.S. +	—				+	—		88 (177)	
								+	—						B.S. +	—						+	89 (180)	
							+	—					B.S. +	—						+	—		90 (181)	
							+	—							B.S. +	—					+	—	91 (184)	
								+	—							B.S. +						+	92 (188)	

RESULTS OF THE BACTERIOLOGICAL EXAMINATI

1						2		3						4		
Description of the Sample.						Total Number of Bacteria in 1 c.c.		Number of B. Coli (or closely allied forms) in 1 c.c.						Chief Biological Cha ters of the *strain* o Coli present in th number specified Col. 3.		
No.	Time of Collection.				Other Details.	Gelatine at 20° C.	Agar at 37° C.							Gas.	Indol.	(a) Aci (b) Cl
	Hour.	Day.	Month.	Year.				1 — 1 c.c.	10 — ·1 c.c.	100 — ·01 c.c.	1,000 — ·001 c.c.	10,000 — ·0001 c.c.	100,000 — ·00001 c.c.	(Gelatine "shake" cultures, 24 hrs. at 20° C.)	(Broth cultures 5 days at 37° C.)	(Litm milk tures, 5 at 37° — (a)
93 (189) ..	3.13 p.m.	5	10	1904	Ducat Final Effluent, No. 2 Filter							+		+	+	+
94 (195) ..	3·28 p.m.	6	10	1904	Ducat Final Effluent, No. 1 Filter							+		+	+	+
95 (196) ..	3.35 p.m.	6	10	1904	Ducat Final Effluent, No. 2 Filter						+			+	—	+
96 (201) ..	3.12 p.m.	7	10	1904	Ducat Final Effluent, No. 1 Filter						+			+	—	+
97 (202) ..	3.20 p.m.	7	10	1904	Ducat Final Effluent, No. 2 Filter						+			+	+	+
98 (232) ..	3.15 p.m.	26	10	1904	Ducat Final Effluent, No. 2 Filter							+		+	+	+
99 (237) ..	3.15 p.m.	28	10	1904	Ducat Final Effluent, No. 2 Filter					+				+	+	+
100 (242) ..	3.20 p.m.	31	10	1904	Ducat Final Effluent, No. 2 Filter					+				+	—	+
101 (244) ..	3.25 p.m.	1	11	1904	Ducat Final Effluent, No. 2 Filter					+				+	—	+
102 (249) ..	3.10 p.m.	2	11	1904	Ducat Final Effluent, No. 2 Filter					+				+	—	+
103 (283) ..	3.5 p.m.	28	11	1904	Ducat Final Effluent, No. 2 Filte							+		+	+	+
104 (288) ..	3.35 p.m.	29	11	1904	Ducat Final Effluent, No. 2 Filter							+		+	+	+
105 (290) ..	3.10 p.m.	30	11	1904	Ducat Final Effluent, No. 2 Filter							+		+	+	+
106 (299) ..	3.15 p.m.	5	12	1904	Ducat Final Effluent, No. 2 Filter							+		+	+	+
107 (305) ..	3.55 p.m.	7	12	1904	Ducat Final Effluent, No. 2 Filter						+			+	+	+
108 (311) ..	3.10 p.m.	13	12	1904	Ducat Final Effluent, No. 2 Filter						+			+	—	+
109 (313) ..	3.20 p.m.	14	12	1904	Ducat Final Effluent, No. 2 Filter						—					
110 (316) ..	3.5 p.m.	16	12	1904	Ducat Final Effluent, No. 2 Filter						+			+	+	+
111 (321) ..	3.15 p.m.	19	12	1904	Ducat Final Effluent, No. 2 Filter						+			+	+	+
112 (325) ..	3.25 p.m.	21	12	1904	Ducat Final Effluent, No. 2 Filter						+			+	+	+
113 (326) ..	3.15 p.m.	28	12	1904	Ducat Final Effluent, No. 2 Filter						+			+	+	+

THE HENDON DUCAT FILTER EFFLUENT—(*continued*).

5				6						7						8						9	
“Gas” Test. ” production in gelatine ” cultures, 24 hours at 20° C.				B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's “enteritidis change” in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						In.=Indol Test. B.S.=Bile-salt glucose peptone test.						Neutral-red Broth Test. Greenish-yellow fluorescence, 48 hours at 37° C.						No.	REMARKS.
100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000		
·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.		
							+	–						B.S. +	–					+	–	93 (189)	
						+	–							B.S. +	–					+	–	94 (195)	
							+	–					B.S. +	–					+	–		95 (196)	
							+	–					B.S +	–							+	96 (201)	
						+	–						B.S. +	–					+	–		97 (202)	
							+	–						B.S. +	–				+	–		98 (232)	
						+	–					B.S. +	–							+	–	99 (237)	
						+	–					B.S. +	–						+	–		100 (242)	
						+	–					B.S. +	–				+	–				101 (244)	
						+	–					B.S +	–							+	–	102 (249)	
						+	–							B.S. +	–					+	–	103 (253)	
						+	–							B.S. +	–					+	–	104 (288)	
							+	–						B.S. +	–					+	–	105 (290)	
						÷	–							B.S. +	–					+	–	106 (290)	
							+	–					B.S. +	–						+	–	107 (305)	
						+	–						B.S. +	–					+	–		108 (311)	
					+	–							B.S. +	–				+	–			109 (313)	
						+	–						B.S. +	–				+	–			110 (316)	
						+	–						B.S. +	–						+	–	111 (321)	
						+	–						B.S. +	–					+	–		112 (325)	
						+	–						B.S. +	–					+	–		113 (326)	

RESULTS OF THE BACTERIOLOGICAL EXAMINATIO

1						2		3						4		
Description of the Sample.						Total Number of Bacteria in 1 c.c.		Number of B. Coli (or closely allied forms) in 1 c.c.						Chief Biological Chr ters of the *strain* Coli present in t number specified Col. 3.		
No.	Time of Collection.				Other Details.	Gelatine at 20° C.	Agar at 37° C.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	Gas. (Gelatine "shake" cultures, 24 hrs. at 20° C.)	Indol. (Broth cultures 5 days at 37° C.)	(a) Ac (b) C (Litn milk tures, at 37 (a)
	Hour.	Day.	Month.	Year.												
114 (328) ..	3.35 p.m.	30	12	1904	Ducat Final Effluent, No. 2 Filter						+			+	+	+
115 (330) ..	3.40 p.m.	2	1	1905	Ducat Final Effluent, No. 2 Filter						+			+	+	+
116 (334) ..	3.35 p.m.	3	1	1905	Ducat Final Effluent, No. 2 Filter					+				+	+	+
117 (337) ..	3.15 p.m.	4	1	1905	Ducat Final Effluent, No. 2 Filter								+	+	—	+
118 (348) ..	3.35 p.m.	6	1	1905	Ducat Final Effluent, No. 2 Filter					+				+	—	+
119 (351) ..	2.35 p.m.	9	1	1905	Ducat Final Effluent, No. 2 Filter						+			+	+	+
120 (353) ..	3.40 p.m.	10	1	1905	Ducat Final Effluent, No. 2 Filter					+				+	+	+
121 (358) ..	3.30 p.m.	11	1	1905	Ducat Final Effluent, No. 2 Filter						+			+	+	+
122 (360) ..	3.20 p.m.	13	1	1905	Ducat Final Effluent, No. 2 Filter						+			+	+	+
123 (363) ..	3.25 p.m.	16	1	1905	Ducat Final Effluent, No. 2 Filter							+		+	+	+
124 (366) ..	3.10 p.m.	17	1	1905	Ducat Final Effluent, No. 2 Filter								+	+	+	+
125 (367) ..	3.25 p.m.	18	1	1905	Ducat Final Effluent, No. 2 Filter					+				+	+	+
126 (371) ..	3.25 p.m.	24	1	1905	Ducat Final Effluent, No. 2 Filter					+				+	+	+
127 (376) ..	3.10 p.m.	25	1	1905	Ducat Final Effluent, No. 2 Filter					+				+	+	+
128 (388) ..	3.10 p.m.	30	1	1905	Ducat Final Effluent, No. 2 Filter						+			+	+	+
AVERAGES:						Gelatine at 20° C. 1,930,090 per c.c. Agar at 37° C. 363,833 per c.c.		11 samples of 100,000; 26 " " 10,000; 26 " " 1,000; 12 " " 100 per c.c. 4 samples negative ·0001 c.c. 1 sample negative ·001 c.c.						51 out of 73 both i and clot. 9 out of 73 neither i nor clot. 8 out of 73 clot, bu indol. 5 out of 73 indol, no clot.		

THE HENDON DUCAT FILTER EFFLUENT—(*continued*).

5					6						7						8						9	
"Gas" Test. [...] production in gelatine [...]" cultures, 24 hours at 20° C.					B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						In.=Indol Test. B.S.=Bile-salt glucose peptone test.						Neutral-red Broth Test. Greenish-yellow fluorescence, 48 hours at 37° C.						No.	REMARKS.
	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000		
c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.		
								+	—					B.S. +	—					+	—		114 (328)	
							+	—						B.S. +	—					+	—		115 (330)	
							+	—					B.S. +	—							+	—	116 (324)	
							+	—							B.S. +	—				+	—		117 (337)	
						+							B.S. +	—					+	—			118 (348)	
							+	—						B.S. +	—						+	—	119 (351)	
							+	—					B.S. +	—							+	—	120 (353)	
						+	—							B.S. +	—					+	—		121 (358)	
							+	—						B.S. +	—				+	—			122 (360)	
							+	—							B.S. +	—					+	—	123 (363)	
							+	—								B.S. +				+	—		124 (366)	
						+	—						B.S. +	—					+	—			125 (367)	
							+	—					B.S. +	—						+	—		126 (371)	
							+	—					B.S. +	—						+	—		127 (376)	
							+	—						B.S. +	—					+	—		128 (388)	
[...] from + ·1 c.c. to + ·01 [...] but more frequently [...] c.c. than + ·01 c.c.					2 samples at 10,000 20 " " 1,000 61 " " 100 16 " " 10 4 " " 1 per c.c.						Indol test— 3 samples at 100,000 4 " " 10,000 1 " " 1,000 per c.c. Bile salt glucose peptone test— 6 samples at 100,000 24 " " 10,000 20 " " 1,000 11 " " 100 per c.c.						18 samples at 100,000 42 " " 10,000 32 " " 1,000 6 " " 100 1 " " 10 per c.c.							

RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF

1						2		3						4			
Description of the Sample.						Total Number of Bacteria in 1 c.c.		Number of B. Coli (or closely allied forms) in 1 c.c.						Chief Biological Chara ters of the *strain* of Coli present in the number specified i Col. 3.			
No.	Time of Collection.				Other Details.	Gelatine at 20° C.	Agar at 37° C.	1	10	100	1,000	10,000	100,000	Gas.	Indol.	(a) Acidi (b) Clot (Litmu milk cu tures, 5 d at 37° C	
	Hour.	Day.	Month.	Year.				1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	(Gelatine "shake" cultures, 24 hrs. at 20° C.)	(Broth cultures 5 days at 37° C.)	(a)	(
1	—	17	7	1900	Final Effluent Ducat's filter, after sand filtration, Hendon.												
(417)	—	18	11	1901	Final Effluent Ducat's, filter after sand filtration, Hendon.	43,000	9,300					+	–	+	+	+	–
3 (424)	—	20	11	1901	Final Effluent Ducat's filter, after sand filtration, Hendon.												
4 (428)	—	26	11	1901	Final Effluent Ducat's filter, after sand filtration, Hendon.	18,000	2,300					–					
5 (432)	—	28	11	1901	Final Fffluent Ducat's filter, after sand fileration, Hendon.												
6 (436)	—	2	12	1901	Final Effluent Ducat's filter, after sand filtration, Hendon.	63,000	3,500				+	–		+	+	+	+
7 (440)	—	4	12	1901	Final Effluent Ducat's filter, after sand filtration, Hendon.												
8	—	10	12	1901	Final Effluent Ducat's filter, after sand filtration, Hendon.	39,000	2,000			–							
9 (79)	2.35 p.m.	28	7	1904	Final Effluent Ducat's filter, after sand filtration, Hendon.												
10 (83)	2.45 p.m.	1	8	1904	Final effluent Ducat's filter, after sand filtration, Hendon.												
1 (88)	3.22 p.m.	3	8	1904	Final Effluent Ducat's filter, after sand filtration, Hendon.												
12 (92)	2.57 p.m.	8	8	1904	Final Effluent Ducat's filter, after sand filtration, Hendon.												
13 (105)	3.30 p.m.	9	8	1904	Final Effluent, Ducat's filter, after sand filtration, Hendon.												
1 (112)	2.50 p.m.	10	8	1904	Final Effluent, Ducat's filter, after sand filtration, Hendon.												
15 (120)	4.24 p.m.	11	8	1904	Final Effluent, Ducat's filter, after sand filtration, Hendon.												
16 (133)	3.25 p.m.	12	9	1904	Final Effluent, Ducat's filter, after sand filtration, Hendon.				+					+	–	+	+
17 (142)	3.27 p.m.	13	9	1904	Final Effluent, Ducat's filter, after sand filtration, Hendon.						+			+	+	+	+

...on Ducat Filter Effluent after Sand Filtration.

5				6						7						8						9	
"Gas" Test. ...roduction in gelatine ..." cultures, 24 hours at 20° C.				B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						In.=Indol Test. B.S.=Bile-salt glucose peptone test.						Neutral-red Broth Test. Greenish-yellow fluorescence, 48 hours at 37° C.						No.	REMARKS.
100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000		
·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	0001 c.c.	·00001 c.c.		
				+	–																	1	
–					+	–								In. +	–					+		2 (417)	
–					+	–													+	–		3 (424)	
				+	–									In. –				+	–			4 (428)	
				+	–														+	–		5 (432)	
					+	–							In. +	–					+	–		6 (436)	
				+	–													+	–			7 (440)	
		–		+	–							In. –					+	–				8	
				–															+	–		9 (79)	
				–														+	–			10 (83)	
				–															+	–		11 (88)	
				+	–													+	–			12 (92)	
				–														+	–			13 (105)	
				–															+	–		14 (112)	
				–														+	–			15 (120)	
				–							B.S. +	–						+	–			16 (138)	
				–									B.S. +	–			+	–				17 (142)	

RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF T

1						2		3						4		
Description of the Sample.						Total Number of Bacteria in 1 c.c.		Number of B. Coli (or closely allied forms) in 1 c.c.						Chief Biological Chara ters of the *strain* of Coli present in the number specified i Col. 3.		
No.	Time of Collection. Hour.	Day.	Month.	Year.	Other Details.	Gelatine at 20° C.	Agar at 37° C.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	Gas. (Gelatine "shake" cultures, 24 hrs. at 20° C.)	Indol. (Broth cultures 5 days at 37° C.)	(a) Acid (b) Clo (Litmu milk c tures, 5 at 37° (a)
18 (145)	3.20 p.m.	14	9	1904	Final Effluent, Ducat's filter, after sand filtration, Hendon.				+					+	–	+
19 (150)	3.28 p.m.	16	9	1904	Final Effluent, Ducat's filter, after sand filtration, Hendon.					+				+	+	+
20 (154)	3.16 p.m.	22	9	1904	Final Effluent, Ducat's filter after sand filtration, Hendon.						+			+	+	+
21 (158)	3.23 p.m.	23	9	1904	Final Effluent, Ducat's filter, after sand filtration, Hendon.				+					+	+	+
22 (162)	3.33 p.m.	26	9	1904	Final Effluent, Ducat's filter, after sand filtration, Hendon.						+			+	–	+
23 (166)	3.36 p.m.	27	9	1904	Final Effluent, Ducat's filter, after sand filtration, Hendon.				+					+	+	+
24 (170)	3.28 p.m.	28	9	1904	Final Effluent, Ducat's filter, after sand filtration, Hendon.				+					+	+	+
25 (174)	3·51 p.m.	29	9	1904	Final Effluent, Ducat's filter, after sand filtration, Hendon.				+					+	–	+
26 (178)	3.38 p.m.	30	9	1904	Final Effluent, Ducat's filter, after sand filtration, Hendon.						+			+	+	+
27 (182)	3.30 p.m.	3	10	1904	Final Effluent, Ducat's filter, after sand filtration, Hendon.				+					+	+	+
28 (190)	3.10 p.m.	5	10	1904	Final Effluent, Ducat's filter, after sand filtration, Hendon.				+					+	+	+
29 (197)	3.33 p.m.	6	10	1904	Final Effluent, Ducat's filter, after sand filtration, Hendon.				+					+	+	+
30 (203)	3.17 p.m.	7	10	1904	Final Effluent, Ducat's filter, after sand filtration, Hendon.					+				+	+	+
31 (233)	3.20 p.m.	25	10	1904	Final Effluent. Ducat's filter, after sand filtration, Hendon						+			+	+	+
32 (233)	3.25 p.m.	28	10	1904	Final Effluent, Ducat's filter, after sand filtration, Hendon.				+					+	+	+
33 (243)	3.25 p.m.	31	10	1904	Final Effluent, Ducat's filter, after sand filtration, Hendon.					+				+	+	+
34 (245)	3.33 p.m.	1	11	1904	Final Effluent, Ducat's filter after sand filtration, Hendon.				+					+	+	+

5					6						7						8						9	
"Gas" Test. " production in gelatine e" cultures, 24 hours at 20° C.					B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						In.=Indol Test. B.S.=Bile-salt glucose peptone test.						Neutral-red Broth Test. Greenish-yellow fluorescence, 48 hours at 37° C.						No.	REMARKS.
c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.		
					–							B.S. +	–						+	–			18 (145)	
					–								B.S. +	–				+	–				19 (150)	
					–									B.S. +	–					+	–		20 (154)	
					–							B.S. +	–					+	–				21 (158)	
					–									B.S. +	–						+	–	22 (162)	
					–							B.S. +						–					23 (166)	
					–							B.S. +	–					+	–				24 (170)	
					–							B.S. +	–						+	–			25 (174)	
					–									B.S. +	–					+	–		26 (178)	
						–						B.S. +						+	–				27 (182)	
					–							B S. +	–					+	–				28 (190)	
					–							B.S. +	–						+	–			29 (197)	
						+	–						B.S. +	–					+	–			30 (203)	
					+	–								B.S. +	–				+	–			31 (233)	
					–							B.S. +	–						+	–			32 (235)	
						+	–						B.S +	–						+	–		33 (243)	
					–							B.S. +	–						+	–			34 (245)	

RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF

1						2		3						4		
Description of the Sample.						Total Number of Bacteria in 1 c.c.		Number of B. Coli (or closely allied forms) in 1 c.c.						Chief Biological C ters of the strai Coli present in number specifi Col. 3.		
No.	Time of Collection.				Other Details.	Gelatine at 20° C.	Agar at 37° C.	1	10	100	1,000	10,000	100,000	Gas.	Indol.	(a) (b) (Li mil ture at
	Hour.	Day.	Month.	Year.				1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	(Gelatine "shake" cultures, 24 hrs. at 20° C.)	(Broth cultures 5 days at 37° C.)	(a)
35 (250)	3.16 p.m.	2	11	1904	Final Effluent, Ducat's filter, after sand filtration, Hendon.						+			+	+	+
36 (291)	3.20 p.m.	30	11	1904	Final Effluent, Ducat's filter, after sand filtration, Hendon.						+			+	+	+
37 (298)	3.18 p.m.	2	12	1904	Final Effluent, Ducat's filter, after sand filtration, Hendon.					+				+	+	+
38 (300)	3 22 a.m.	5	12	1904	Final Effluent, Ducat's filter, after sand filtration, Hendon.				+					+	+	+
39 (304)	3.10 p.m.	6	12	1904	Final Effluent, Ducat's filter, after sand filtration, Hendon.					+				+	+	+
40 (306)	4 p.m.	7	12	1904	Final Effluent, Ducat's filter, after sand filtration, Hendon.					+				+	+	+
41 (312)	3.18 p.m.	13	12	1904	Final Effluent, Ducat's filter, after sand filtration, Hendon.					+				+	—	+
42 (314)	3.30 p.m.	14	12	1904	Final Effluent, Ducat's filter, after sand filtration, Hendon.				+					+	—	+
43 (317)	3.10 p.m.	16	12	1904	Final Effluent, Ducat's filter, after sand filtration, Hendon.				+					+	+	+
44 (322)	3.22 p.m.	19	12	1904	Final Effluent Ducat's filter, after sand filtration, Hendon.					+				+	+	+
45 (327)	3.20 p.m.	28	12	1904	Final Effluent, Ducat's filter, after sand filtration, Hendon.						+			+	+	+
46 (329)	3.41 p.m.	30	12	1904	Final Effluent, Ducat's filter, after sand filtration, Hendon.					+				+	+	+
47 (338)	3.20 p.m.	4	1	1905	Final Effluent, Ducat's filter, after sand filtration, Hendon.					+				+	+	+
48 (352)	2.40 p.m.	9	1	1905	Final Effluent, Ducat's filter, after sand filtration, Hendon.					+				+	—	+
49 (354)	3.45 p.m.	10	1	1905	Final Effluent, Ducat's filter, after sand filtration, Hendon.					+				+	—	+
50 (359)	3.37 p.m.	11	1	1905	Final Effluent, Ducat's filter, after sand filtration, Hendon.				+					+	+	+
51 (261)	3.25 p.m.	13	1	1905	Final Effluent, Ducat's filter, after sand filtration, Hendon.					+				+	+	+
52 (377)	3.15 p.m.	25	1	1905	Final Effluent, Ducat's filter, after sand filtration, Hendon.					+				+	+	+

AVERAGES:

Gelatine at 20° C. 40,750 } per c.c.
Agar at 37° C. 4,275 }

1 sample at 10,000 }
9 samples at 1,000 } per c.c.
14 samples at 100 }
15 samples at 10 }
1 sample negative ·0001 c.c.
1 sample negative ·01 c.c.

31 out of 39 indol a
1 out of 39 neither nor clo
7 out of 39 clot b indol.

ndon Ducat Filter Effluent after Sand Filtration—*Continued.*

5						6						7						8						9	
"Gas" Test. "Gas" production in gelatine "shake" cultures, 24 hours at 20° C.						B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						In.=Indol Test. B.S.=Bile-salt glucose peptone test.						Neutral-red Broth Test. Greenish-yellow fluorescence, 48 hours at 37° C.						No.	REMARKS.
1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000		
1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	0001 c.c.	·00001 c.c.		
						–									B.S. +	–				+	–			35 (250)	
							+	–							B.S. +	–					+	–		36 (291)	
						+	–							B.S. +	–					+	–			37 (298)	
						–							B.S. +	–						+	–			38 (300)	
						+	–							B.S. +	–					+	–			39 (304)	
						–								B.S. +	–				+	–				40 (306)	
						–								B.S. +	–						+	–		41 (312)	
						+	–						B.S. +	–						+	–			42 (314)	
						+	–						B.S. +	–						+	–			43 (317)	
						+	–							B.S. +	–						+	–		44 (322)	
							+	–							B.S. +						+			45 (327)	
						–								B.S. +	–				+	–				46 (329)	
						+	–							B.S. +	–					+	–			47 (338)	
						+	–							B.S. +	–				+	–				48 (352)	
						–								B.S. +	–						+	–		49 (354)	
						+	–						B.S. +	–						+	–			50 (359)	
						–								B.S. +	–					+	–			51 (361)	
						–								B.S. +	–					+	–			52 (377)	

ried between negative 1 c.c. and positive ·1 c.c.

7 samples at 10 } per c.c.
15 samples at 1 }

29 samples negative 1 c.c.
1 sample negative ·1 c.c.

Indol test:
1 sample 10,000 } per c.c.
1 sample 1,000 }
1 sample negative ·0001 c.c.
1 sample negative ·01 c.c.
Bile salt glucose peptone test:
8 samples 1,000 } per c.c.
14 samples 100 }
15 samples 10 }

2 samples 10,000 } per c.c.
14 samples 1,000 }
24 samples 100 }
10 samples 10 }
1 sample negative ·1 c.c.

HENDON.

SUMMARY OF RESULTS.

Crude Sewage.

Total Number of Bacteria per c.c.

Gelatine at 20° C.

7 Samples.

Average number - - - - - - -	25,985,714
Greatest number - - - - - - -	46,400,000
Smallest number - - - - - - -	8,700,000

Approximate Estimate.

6 samples over 10,000,000 bacteria per c.c.

1 sample over 1,000,000 bacteria per c.c.

Agar at 37° C.

20 Samples.

Average number - - - - - - -	7,525,500
Greatest number - - - - - - -	15,000,000
Smallest number - - - - - - -	730,000

Approximate Estimate.

7 samples (35 per cent.) 10,000,000 bacteria per c.c.

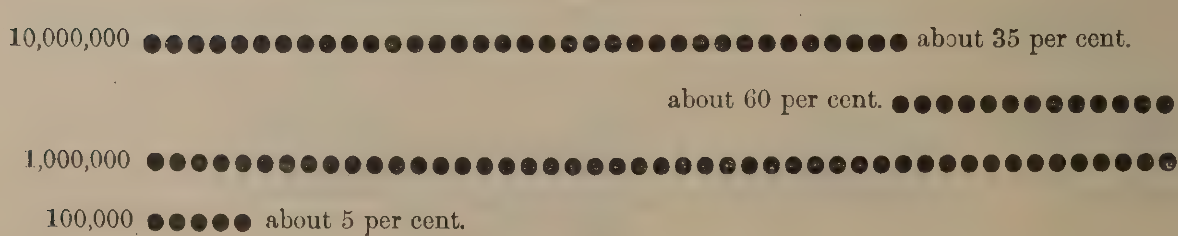
12 samples (60 per cent.) 1,000,000 bacteria per c.c.

1 sample (5 per cent.) - 100,000 bacteria per c.c.

These results may be illustrated by a diagram as follows:—

Hendon Crude Sewage.

Total Number of Bacteria (Agar at 37° C.).



Hendon Crude Sewage.

Number of B. Coli or Coli-like Microbes.

21 Samples.

Approximate Estimate.

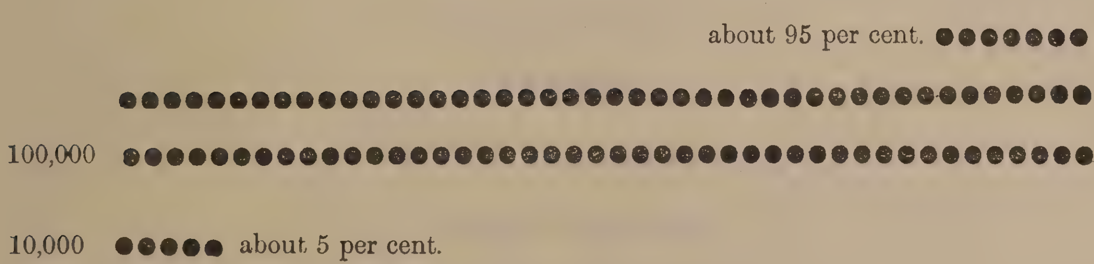
20 samples (about 95 per cent.) 100,000 per c.c.

1 sample (about 5 per cent.) 10,000 per c.c.

These results may be illustrated by a diagram as follows:—

Hendon Crude Sewage.

B. Coli Test.



With regard to the biological attributes of the B. coli or coli-like microbes isolated from the samples, about 80 per cent. were, on the basis of the tests employed, typical B. coli.

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* N.B.– It should be noted that the B. coli, indol, bile salt glucose peptone and neutral red broth tests were not "pushed" beyond $\frac{1}{100000}$ c.c.

Hendon Crude Sewage.

Indol Test.

(Indol in broth cultures, 5 days at 37° C.)

4 Samples.

Approximate Estimate.

All 4 samples 100,000 per c.c.

The samples were, in this instance, too few in number to render it desirable to append a diagram.

Bile Salt Glucose Peptone Test.

14 Samples.

Approximate Estimate.

All 14 samples (100 per cent.) 100,000 per c.c.

As all the samples examined by this test yielded the same result, it is unnecessary to append a diagram.

Hendon Crude Sewage.

B. Enteritidis Sporogenes Test.

32 Samples.

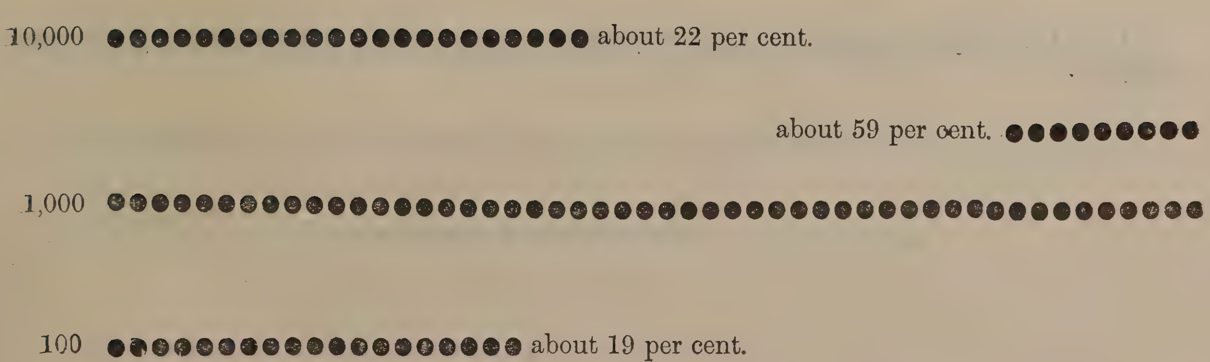
Approximate Estimate.

7 samples	(about 22 per cent.)	10,000 per c.c.
19 ,,	(about 59 per cent.)	1,000 per c.c.
6 ,,	(about 19 per cent.)	100 per c.c.

These results may be illustrated by a diagram, as follows:—

Hendon Crude Sewage.

B. Enteritidis Sporogenes Test.



Hendon Crude Sewage.

Gas Test.

Gelatine "shake" cultures 24 hours at 20° C.

7 samples.

1 sample positive result with ·0001 c.c.

6 samples positive result with ·001 c.c.

The samples were in this instance too few in number to render it desirable to append a diagram.

Neutral Red Broth Test.

29 samples.

All 29 samples (100 per cent.) 100,000 per c.c.

As all the samples examined by this test yielded the same result, it is unnecessary to append a diagram.

Hendon Ducat Filter Effluents.*

Total Number of Bacteria per c.c.

Gelatine at 20° C.

11 Samples.

Average number	- - - - - - -	1,930,090
Greatest number	- - - - - - -	7,600,000
Smallest number	- - - - - - -	50,000

Approximate Estimate.

4 samples (about 36 per cent.) 1,000,000 bacteria per c.c.

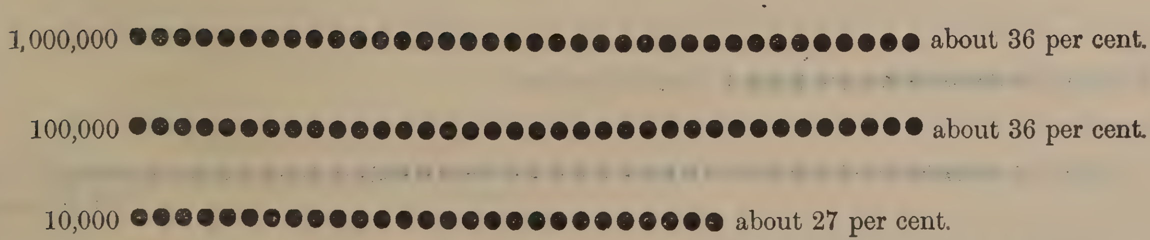
4 samples (about 36 per cent.) 100,000 bacteria per c.c.

3 samples (about 27 per cent.) 10,000 bacteria per c.c.

These results may be illustrated by a diagram as follows :—

Hendon Ducat Filter Effluent.

Gelatine at 20° C.



* The effluents from filters 1 and 2, are for convenience incorporated together in summarising the results.

Hendon Ducat Filter Effluent.

Agar at 37° C.

36 Samples.

Average number 363,863.

Greatest number 1,760,000.

Smallest number, 7,040.

Approximate Estimate.

5 samples	(about 14 per cent.)	1,000,000	bacteria	per c.c.
16 samples	(about 44 per cent.)	100,000	„	„
14 samples	(about 39 per cent.)	10,000	„	„
1 sample	(about 2 per cent.)	1,000	„	„

These results may be illustrated by a diagram as follows:—

Hendon Ducat Filter Effluent.

Agar at 37° C.

1,000,000 ●●●●●●●●●●●●●● about 14 per cent.

100,000 ●● about 44 per cent.

10,000 ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●● about 39 per cent.

1,000 ●● about 2 per cent.

Hendon Ducat Filter Effluent.

Number of B. Coli or Coli-like Microbes.

80 Samples.

Approximate Estimate.

11 samples (about 14 per cent.)	100,000 per c.c.
26 samples (about 32 per cent.)	10,000 per c.c.
26 samples (about 32 per cent.)	1,000 per c.c.
12 samples (about 15 per cent.)	100 per c.c.

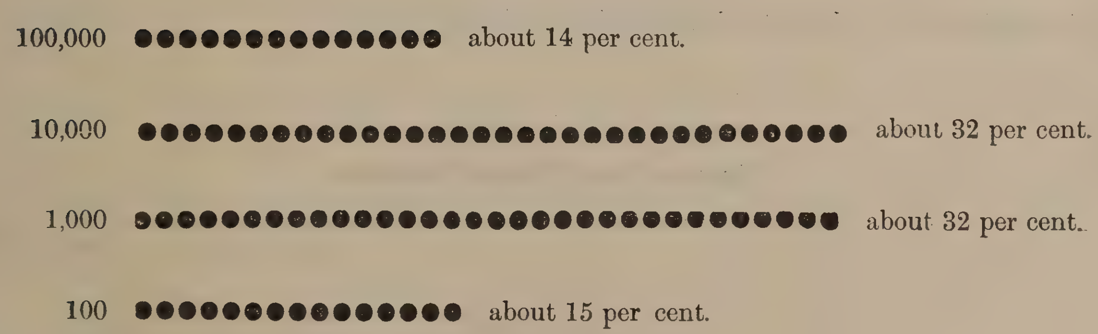
4 samples (about 5 per cent.), negative result with ·0001 c.c.

1 sample (about 1 per cent.), negative result with ·001 c.c.

These results may be illustrated by a diagram as follows:—

Hendon Ducat Filter Effluent.

B. coli or coli-like microbes.



Negative ·0001 c.c. about 5 per cent.

Negative ·001 c.c. about 1 per cent.

With regard to the biological attributes of the B. coli or coli-like microbes isolated from the samples, about 69 per cent. were, on the basis of the tests employed, typical B. coli.

HENDON DUCAT FILTER EFFLUENT.

GAS TEST.

Gas in gelatine "shake" cultures, 24 hours at 20° C.

14 Samples.

Approximate Estimate.

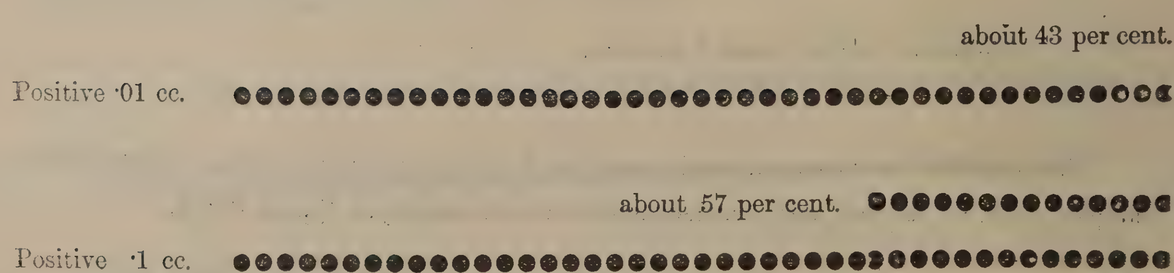
6 samples (about 43 per cent.) positive ·01 c.c.

8 samples (about 57 per cent.) positive ·1 c.c.

These results may be illustrated by the following diagram :—

HENDON DUCAT FILTER EFFLUENT.

Gas Test.



Hendon Ducat Filter Effluent.

B.—Enteritidis Sporogenes Test.

103 Samples.

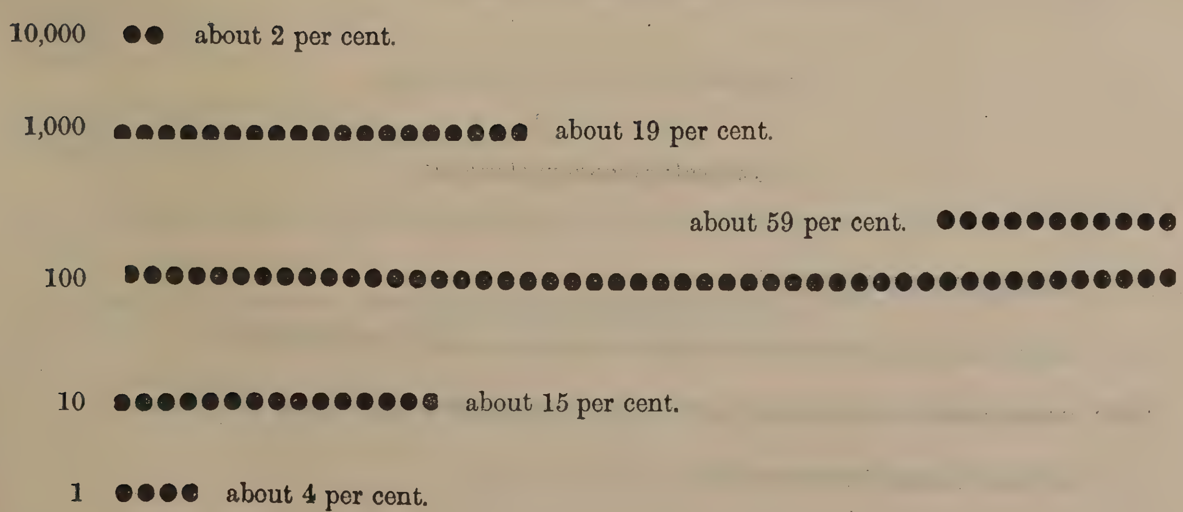
Approximate Estimate.

2 samples	(about 2 per cent.)	10,000 per c.c.
20 samples	(about 19 per cent.)	1,000 per c.c.
61 samples	(about 59 per cent.)	100 per c.c.
16 samples	(about 15 per cent.)	10 per c.c.
4 samples	(about 4 per cent.)	1 per c.c.

These results may be illustrated by a diagram as follows:—

Hendon Ducat Filter Effluent.

B. enteritidis sporogenes test.



Hendon Ducat Filter Effluent.

Indol Test.

Indol in broth cultures, 5 days at 37° C.

8 Samples.

Approximate Estimate.

3 samples	100,000 per c.c.
4 samples	10,000 per c.c.
1 sample	1,000 per c.c.

The samples were in this instance too few in number to render it desirable to append a diagram.

Bile Salt Glucose Peptone Test.

61 Samples.

Approximate Estimate.

6 samples	(about 10 per cent.)	100,000 per c.c.
24 samples	(about 39 per cent.)	10,000 per c.c.
20 samples	(about 33 per cent.)	1,000 per c.c.
11 samples	(about 18 per cent.)	100 per c.c.

These results may be illustrated by a diagram as follows:—

Hendon Ducat Filter Effluent.

Bile salt glucose peptone test.

100,000 ●●●●●●●●●● about 10 per cent.

10,000 ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●● about 39 per cent.

1,000 ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●● about 33 per cent.

100 ●●●●●●●●●●●●●●●●●● about 18 per cent.

Hendon Ducat Filter Effluent.

Neutral Red Broth Test.

99 Samples.

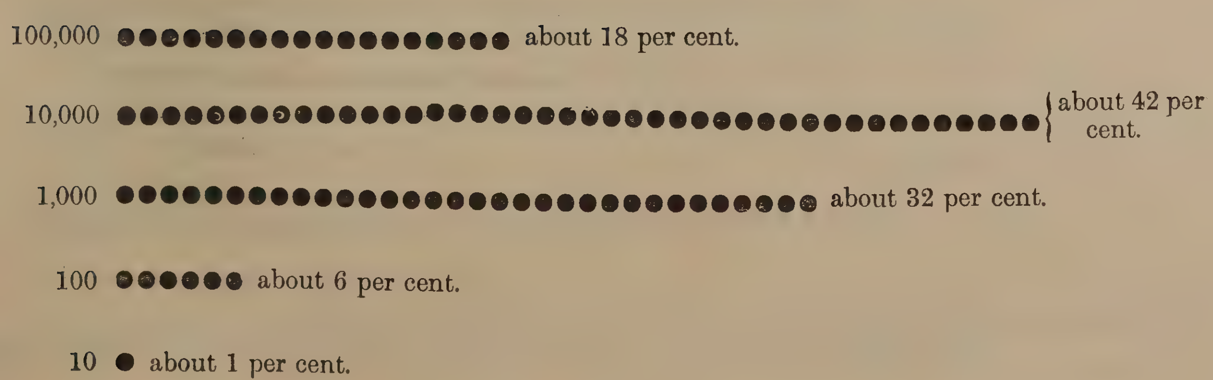
Approximate Estimate.

18 samples	(about 18 per cent.)	100,000 per c.c.
42 samples	(about 42 per cent.)	10,000 per c.c.
32 samples	(about 32 per cent.)	1,000 per c.c.
6 samples	(about 6 per cent.)	100 per c.c.
1 sample	(about 1 per cent.)	10 per c.c.

These results may be illustrated by a diagram as follows:—

Hendon Ducat Filter Effluent.

Neutral red broth test.



Hendon Ducat Filter Effluent after Sand Filtration.

Total Number of Bacteria per c.c.

Gelatine at 20° C.

4 Samples.

Average number	40,750
Greatest number	63,000
Smallest number	18,000

Agar at 37° C.

4 Samples.

Average number	4,275
Greatest number	9,300
Smallest number	2,000

Hendon Ducat Filter Effluent after Sand Filtration.

Number of B. Coli or Coli-like Microbes.

41 Samples.

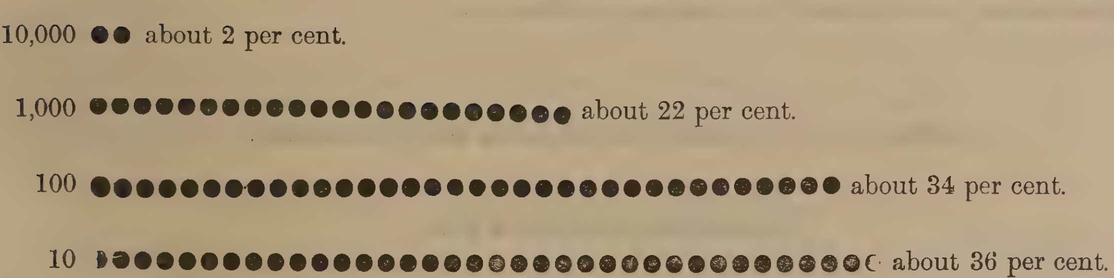
Approximate Estimate.

1 sample	(about 2 per cent.)	10,000 per c.c.
9 samples	(about 22 per cent.)	1,000 per c.c.
14 „	(about 34 per cent.)	100 per c.c.
15 „	(about 36 per cent.)	10 per c.c.
1 sample	(about 2 per cent.)	negative ·01 c.c.
1 „	(about 2 per cent.)	negative ·0001 c.c.

These results may be illustrated by a diagram as follows:—

Hendon Ducat Filter Effluent after Sand Filtration.

Number of B. Coli or Coli-like microbes.



Negative ·0001 about 2 per cent.

Negative ·01 about 2 per cent.

With regard to the biological attributes of the B. Coli or Coli-like microbes isolated from the samples, about 79 per cent. were, on the basis of the tests employed, typical B. Coli.

Hendon Ducat Filter Effluent after Sand Filtration.

Gas Test.

7 samples.

Gas in gelatine "shake" cultures 24 hours at 20° C.

2 samples, positive result with ·1 c.c.

2 samples, positive result with 1 c.c.

3 samples, negative result with 1 c.c.

The samples were in this instance too few in number to render it desirable to append a diagram.

B. Enteritidis Sporogenes Test.

52 samples.

Approximate Estimate.

7	samples	(about 13 per cent.)	10 per c.c.
15	„	(about 29 per cent.)	1 per c.c.
29	„	(about 56 per ce t.)	negative 1 c.c.
1	„	(about 2 per cent.)	negative ·1 c.c.

These results may be illustrated by a diagram as follcws :—

Hendon Ducat Filter Effluent after Sand Filtration.

B. Enteritidis Sporogenes Test.

10 ●●●●●●●●●●●●● about 13 per cent.

1 ●●●●●●●●●●●●●●●●●●●●●●●●●●●●● about 29 per cent.

Negative 1 c.c. about 56 per cent.

Negative ·1 c.c. about 2 per cent.

Hendon Ducat Filter Effluent after Sand Filtration.

Indol Test.

(Indol in broth cultures, 5 days at 37° C.)

4 Samples.

1 sample 10,000 per c.c.

1 sample 1,000 per c.c.

1 sample negative result with ·0001 c.c.

1 sample negative result with ·01 c.c.

The samples were, in this instance, too few in number to render it desirable to append a diagram.

Bile Salt Glucose Peptone Test.

37 Samples.

Approximate Estimate.

8 samples (about 22 per cent.) 1,000 per c.c.

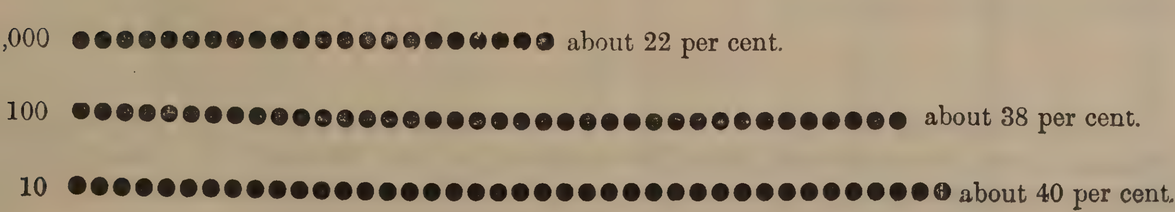
14 samples (about 38 per cent.) 100 per c.c.

15 samples (about 40 per cent.) 10 per c.c

These results may be illustrated by a diagram as follows:—

Hendon Ducat Filter Effluent after Sand Filtration.

Bile Salt Glucose Peptone Test.



Hendon Ducat Filter Effluent after Sand Filtration.

Neutral Red Broth Test.

51 Samples.

Approximate Estimate.

2 Samples	(about 4 per cent.)	10,000 per c.c.
14 Samples	(about 27 per cent.)	1,000 per c.c.
24 Samples	(about 47 per cent.)	100 per c.c.
10 Samples	(about 20 per cent.)	10 per c.c.
1 Sample	(about 2 per cent.)	negative ·1 c.c.

These results may be illustrated by a diagram as follows:—

Hendon Ducat Filter Effluent after Sand Filtration.

Neutral red broth test.

10,000 ●●●● about 4 per cent.

1,000 ●●●●●●●●●●●●●●●●●●●●●●●●●●● about 27 per cent.

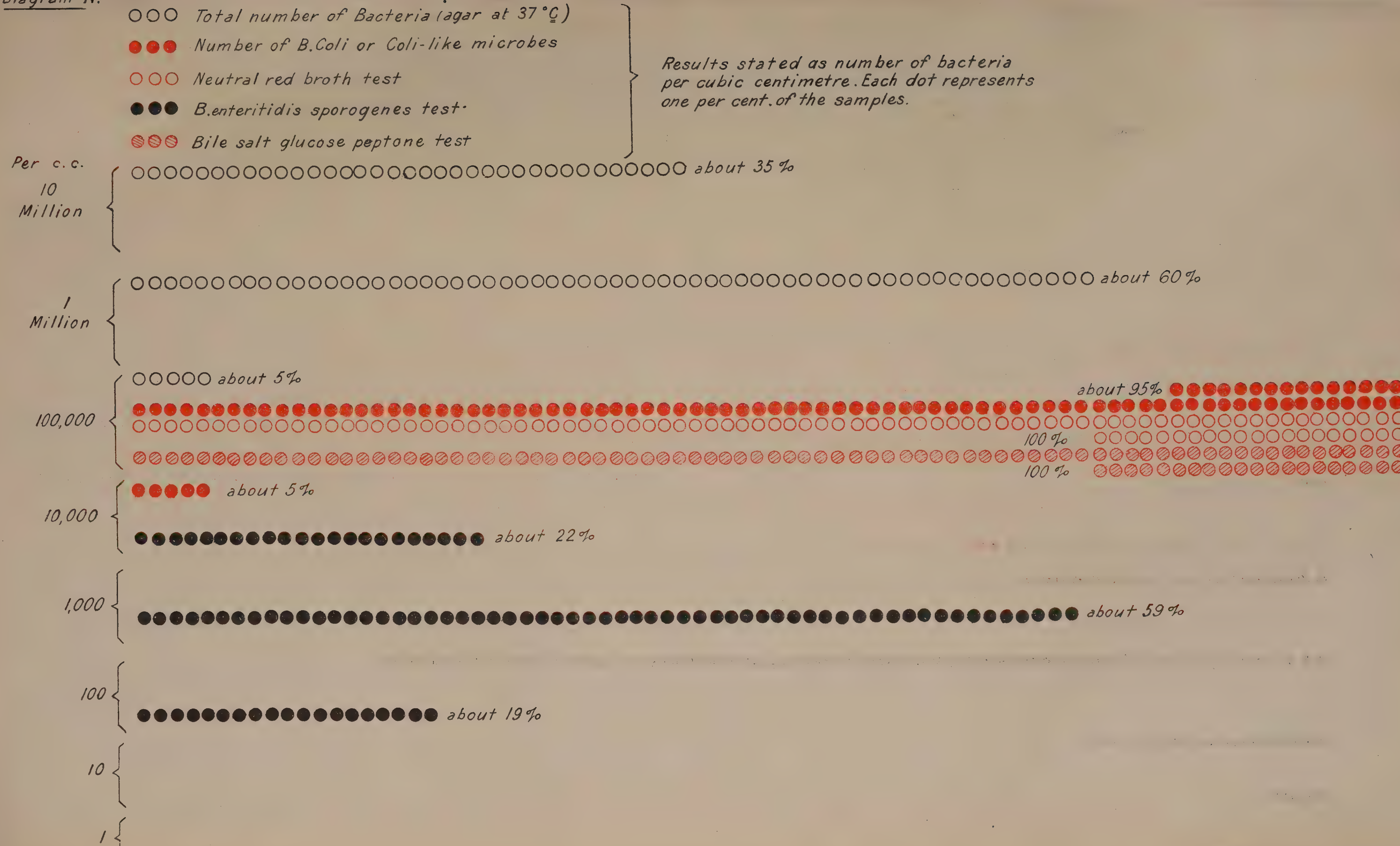
100 ●●● about 47 per cent.

10 ●●●●●●●●●●●●●●●●●●●● about 20 per cent.

Negative ·1 c.c., about 2 per cent.

In order to facilitate comparison between the behaviour towards some of the tests employed of Hendon crude sewage, Hendon Ducat Filter effluent, and the Hendon Ducat Filter effluent subsequent to sand filtration, reference should be made to Diagrams N, O, P, and Q.

Diagram N.



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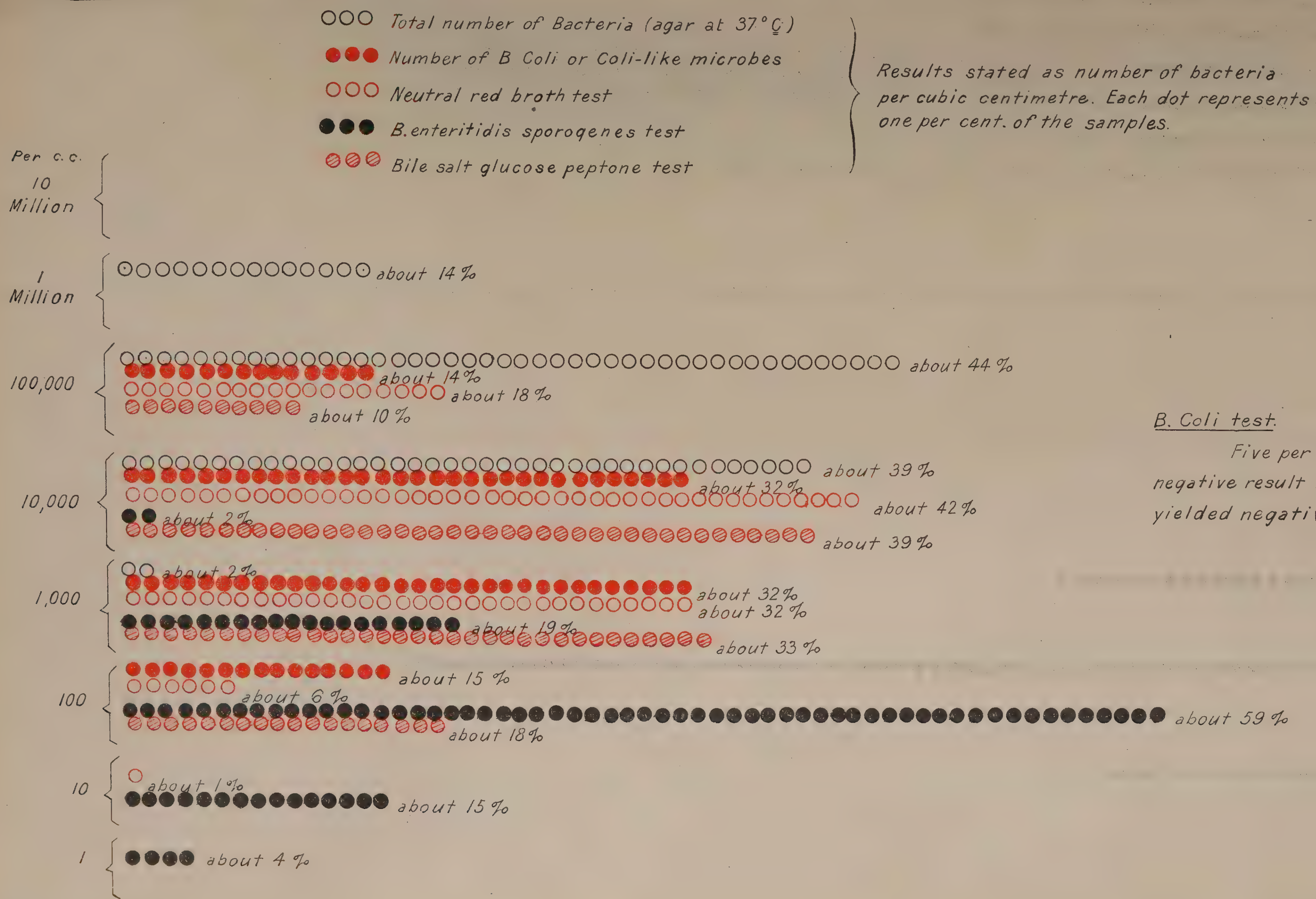
Weller & Graham, Ltd. Litho. London.

Diagram O.



B. Coli test.

Five per cent. of the samples yielded negative result with ·0001 c.c and one per cent yielded negative result with ·001 c.c.

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Diagram P.

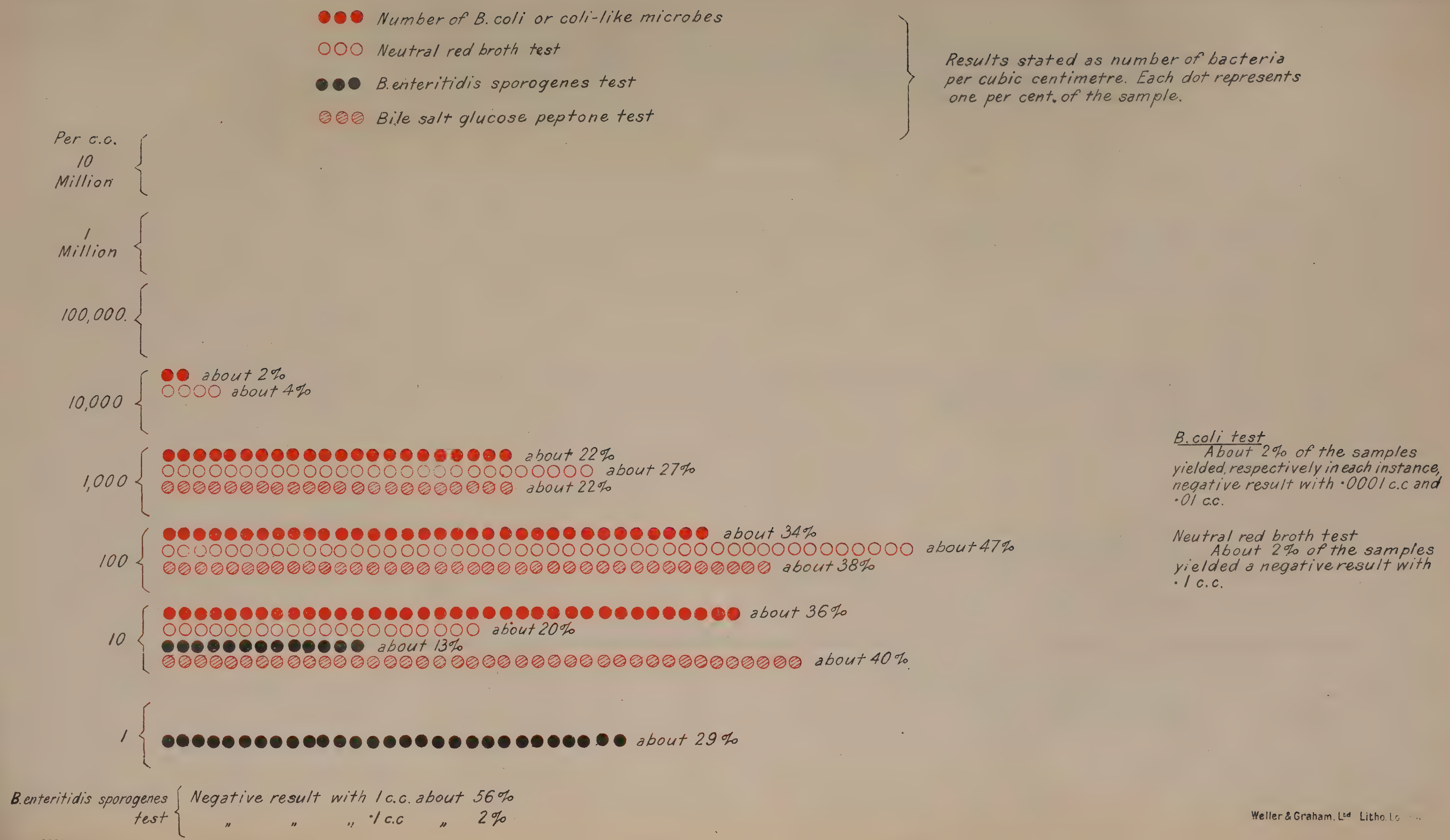

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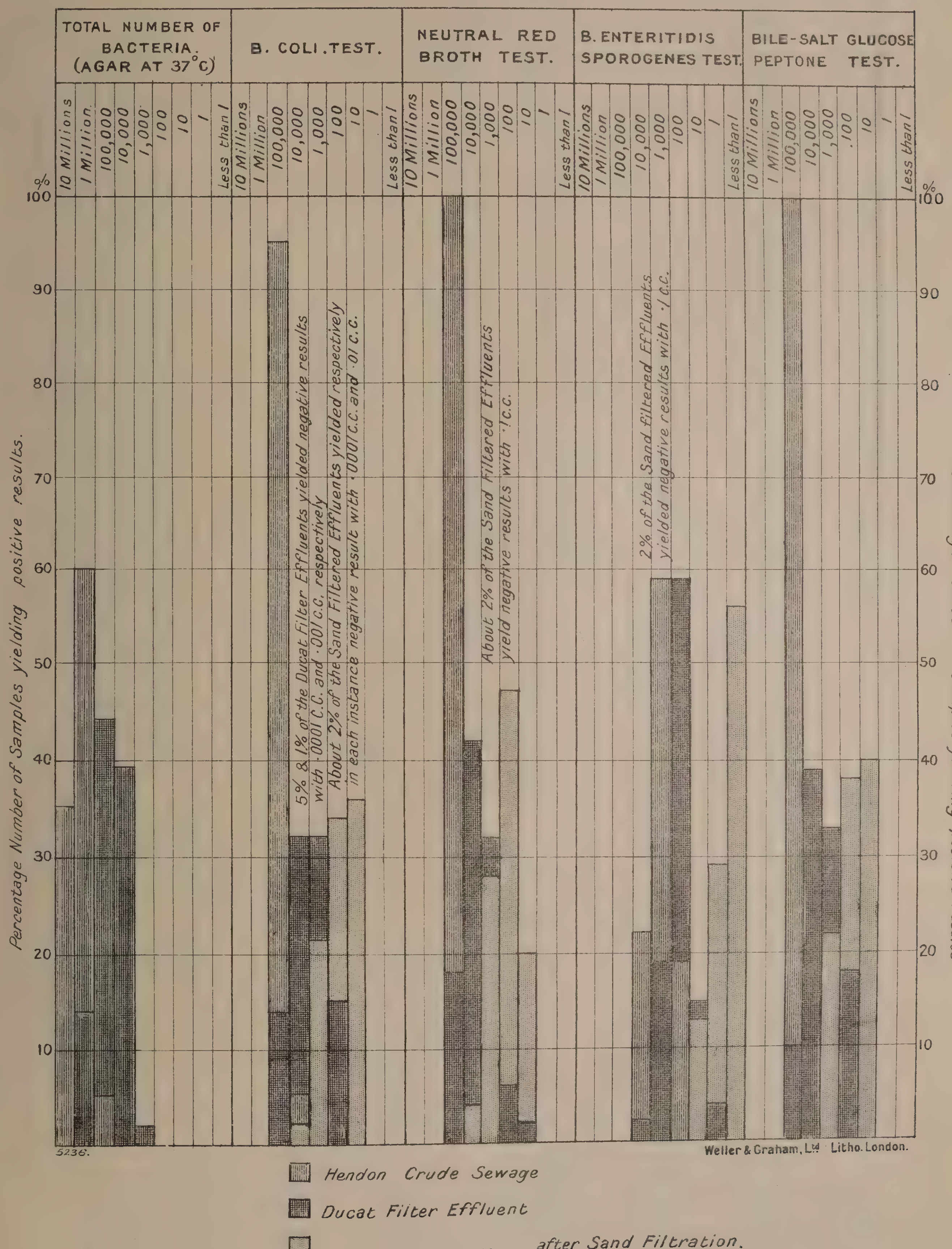
DIAGRAM Q. *Showing the results of the Bacteriological Examination of Hendon crude sewage, Ducat filter effluent and Ducat filter effluent after sand filtration.*

Per c.c., in each instance.



GENERAL REMARKS.

The investigation of the biological quality of Hendon crude sewage and of the effluents from the Ducat filters has been carried out at intervals during a period of five years (1899 to 1904 inclusive).

The Crude Sewage, as regards the total number of microbes capable of growing on agar at 37° C., yielded results as follows:—About 35 per cent. of the samples ten million per c.c.; about 60 per cent. one million per c.c.; about 5 per cent. 100,000 per c.c. Thus, about 95 per cent. of the samples contained one million or more such bacteria per c.c.

The results of the B. coli, neutral-red broth and bile salt glucose peptone tests, taken as a whole, would indicate that the crude sewage practically always yielded a positive result with $\frac{1}{100000}$ c.c. (·00001 c.c.).

Judged by the B. enteritidis sporogenes test, 22 °/₀ of the samples yielded positive result with $\frac{1}{10000}$ c.c. (·0001 c.c.); 59 % yielded positive result with $\frac{1}{1000}$ c.c. (·001 c.c.); 19 % yielded positive result with $\frac{1}{100}$ c.c. (·01 c.c.).

For graphical representation of the results, see Diagram N.

The effluents from the Ducat Filters Nos. 1 and 2 are for convenience incorporated together, in making comparison of the results of the bacteriological examination.

With regard to the total number of microbes capable of growing on agar at 37° C., about 14 % of the effluents contained 1 million per c.c.; about 44 % contained 100,000 per c.c.; about 39 % contained 10,000 per c.c.; about 2 % contained 1,000 per c.c.

About 85 per cent. of the samples contained per c.c. less than one million bacteria capable of growing in agar at 37° C.; whereas 95 per cent. of the samples of sewage contained per c.c., one million or more of such bacteria.

The results of the B. coli, neutral-red broth and bile salt glucose peptone tests are broadly parallel, considered as a whole.

The actual percentage figures are as follows:—

HENDON DUCAT FILTER EFFLUENTS.

Positive Result with—	B. Coli Test.	Neutral red Broth Test.	Bile Salt Glucose Peptone Test.
$\frac{1}{100000}$ c.c. ·00001 c.c. At least 100,000 per c.c.	About 14 per cent.	About 18 per cent.	About 10 per cent.
$\frac{1}{10000}$ c.c. ·0001 c.c. At least 10,000 per c.c.	About 32 per cent.	About 42 per cent.	About 39 per cent.
$\frac{1}{1000}$ c.c. ·001 c.c. At least 1,000 per c.c.	About 32* per cent.	About 32 per cent.	About 33 per cent.
$\frac{1}{100}$ c.c. ·01 c.c. At least 100 per c.c.	About 15† per cent.	About 6 per cent.	About 18 per cent.

* About 5 per cent. yielded negative result with ·0001 c.c.

† About 1 per cent. yielded negative result with ·001 c.c.

Considering together the results of the three foregoing tests, about six out of every seven samples of the Ducat filter effluent yielded *negative* results with $\frac{1}{100000}$ c.c. (·00001 c.c.); whereas practically all the samples of sewage yielded, when examined by these tests, *positive* results with $\frac{1}{100000}$ c.c. (·00001 c.c.).

Further, about half of the samples of the Ducat effluent yielded a negative result with $\frac{1}{10000}$ c.c. (·0001 c.c.)

Judged by the B enteritidis sporogenes test, the effluents from the Ducat filters were, generally speaking, about ten times purer than the crude sewage. For example, 59 per cent. of the samples of sewage yielded positive result with $\frac{1}{1000}$ c.c. (·001 c.c.) when submitted to this test; whereas 59 per cent. of the samples of the Ducat effluents yielded positive result with $\frac{1}{100}$ c.c. (·01 c.c.).

For graphical representation of the results, see Diagram O. During the later stages of the investigation the results were, on the whole, not so satisfactory as during the earlier period of the inquiry. Possibly this result was due to an increasingly large amount of suspended matter being washed out of the filters.

But there can be no question that the Ducat process is capable of effecting, for a prolonged period, a remarkable reduction in the number of bacteria in sewage.

The results of the examination of the effluent from the Ducat filters after filtration through sand are, as regards the B. coli, neutral red broth and bile salt glucose peptone tests, broadly parallel. The actual percentage figures are as follows:—

HENDON DUCAT FILTER EFFLUENTS AFTER SAND FILTRATION.

Positive Result with—	B. Coli Test.	Neutral-Red Broth Test.	Bile Salt Glucose Peptone Test.
$\frac{1}{10000}$ c.c. - - - - - ·0001 c.c. - - - - - At least 10,000 per c.c. -	About 2 per cent.	About 4 per cent.	——
$\frac{1}{1000}$ c.c. - - - - - ·001 c.c. - - - - - At least 1,000 per c.c. -	About 22* per cent.	About 27 per cent.	About 22 per cent.
$\frac{1}{100}$ c.c. - - - - - ·01 c.c. - - - - - At least 100 per c.c. -	About 34 per cent.	About 47 per cent.	About 38 per cent.
$\frac{1}{10}$ c.c. - - - - - ·1 c.c. - - - - - At least 10 per c.c. - -	About 36† per cent.	About 20‡ per cent.	About 40 per cent.

* About 2 per cent. yielded negative result with ·0001 c.c.
† About 2 per cent. yielded negative result with ·01 c.c.
‡ About 2 per cent. yielded negative result with ·1 c.c.

Considering together the results of the three foregoing tests, all the samples of the Ducat effluent after sand filtration yielded a negative result with $\frac{1}{100000}$ c.c. (·00001 c.c.); about 97 per cent. of the samples yielded a negative result with $\frac{1}{10000}$ c.c. (·0001 c.c.); and the great majority gave a negative result with $\frac{1}{1000}$ c.c. (·001 c.c.).

Judged by the B. enteritidis sporogenes test, 56 per cent. of the samples of Ducat effluent after sand filtration yielded negative result with 1 c.c. Speaking generally on the basis of the combined results, the effluents from the Ducat filters were after sand filtration, considered by the results of this test, more than one hundred times purer than the effluents previous to sand filtration, and more than one thousand times purer than the Hendon crude sewage. It has been proposed in certain cases to subject sewage effluents to a final process of sand filtration. Unquestionably the foregoing results indicate that such treatment would reduce the number of bacteria to a remarkable extent.

For graphical representation of the results, see Diagram P.

With regard to the biological characters exhibited by microbes of the coli group isolated from the samples of (*a*) Hendon crude sewage, (*b*) effluents from the Ducat filters, and (*c*) effluents from the Ducat filters subsequent to sand filtration, 80 per cent. of the coli microbes (21 specimens) isolated from (*a*) were identical with typical B. coli as regards formation of indol in broth cultures and production in litmus milk cultures of acidity and clotting; 69 per cent. of such microbes (73 specimens) isolated from (*b*) were similarly typical; and 79 per cent. of the microbes (39 specimens) isolated from (*c*). From this it appears that with regard to the microbes of the coli group isolated from samples of Hendon crude sewage and from Ducat filter effluents, before and after sand filtration, the *proportion* of B. coli which formed indol and acid clotting to coli-like microbes which were deficient in one or other of these attributes, does not vary within very wide limits.

Further, it is obvious that the proportion of typical B. coli (as judged by the foregoing tests) to atypical coli-like microbes is great. Inasmuch as the effluents from the sand filter yielded *proportionately* as many typical B. coli (on the basis of the tests employed) as the sewage, it cannot be said that the treatment effected any appreciable modification of the biological attributes of these intestinal microbes.

In Diagram Q the results of the bacteriological examination of Hendon crude sewage, Ducat filter effluent, and Ducat filter effluent after sand filtration, are brought into comparison. On a percentage basis of comparison the effluents were remarkably good.

ADDENDUM.

CONSIDERATION OF THE BACTERIOLOGICAL RESULTS IN RELATION TO PROVISIONAL STANDARDS.

(NON-DRINKING WATER STREAMS.)

It is of interest to consider the foregoing results in relation to the primary and secondary standards, which have been tentatively suggested by me in previous reports to the Commission, for effluents destined to discharge into non-drinking water streams. I desire to take this opportunity of once more emphasising the statement that any standards which I have suggested, whether as regards drinking water streams, non-drinking water streams, potable waters, estuarial waters or shell fish, are provisional in character, being intended merely for comparative purposes, and have no administrative significance.

Tests.	Effluents Destined to Discharge into Non-drinking Water Streams.	
	Primary Standards.	Secondary Standards.
Total number of bacteria (gelatine at 20° C.)	Less than 100,000 per c.c.	Less than 1,000,000 per c.c.
Total number of bacteria (agar at 37° C.)	Less than 10000 per c.c.	Less than 100,000 per c.c.
B. coli test Indol test Bile salt glucose peptone test Neutral red broth test	Less than 1,000 per c.c. (− ·001 c.c.)	Less than 10,000 per c.c. (·0001 c.c.)
Gas test (gas in gelatine "shake" cultures 24 hours at 20° C.) B. enteritidis sporogenes test	Less than 10 per c.c. (− ·1 c.c.)	Less than 100 per c.c. (− ·01 c.c.)

Description of Sample and Tests.	Primary Standards.		Secondary Standards.	
	"Passed."	"Rejected."	"Passed."	"Rejected."
Hendon Crude Sewage.				
Total number of bacteria (gelatine at 20° C.)	None out of 7.	All 7.	None out of 7.	All 7.
Total number of bacteria (agar at 37° C.)	None out of 20.	All 20 (100 per cent.)	None out of 20.	All 20 (100 per cent.)
B. coli test	None out of 21.	All 21 (100 per cent).	None out of 21.	All 21 (100 per cent.)
Indol test	None out of 4.	All 4.	None out of 4.	All 4.
Bile-salt glucose peptone test	None out of 14.	All 14 (100 per cent.)	None out of 14.	All 14 (100 per cent.)
Neutral red broth test	None out of 29.	All 29 (100 per cent.)	None out of 29.	All 29 (100 per cent.)
Gas test (24 hours at 20° C.)	None out of 7.	All 7.	None out of 7.	All 7.
B. enteritidis sporogenes test	None out of 32.	All 32 (100 per cent.)	None out of 32.	All 32 (100 per cent.)
Hendon Ducat Filter Effluent.				
Total number of bacteria (gelatine at 20° C.)	3 out of 11 (27 per cent.)	8 out of 11 (73 per cent.)	7 out of 11 (64 per cent.)	4 out of 11 (36 per cent.)
Total number of bacteria (agar at 37° C.)	1 out of 36 (3 per cent.)	35 out of 36 (97 per cent.)	15 out of 36 (42 per cent.)	21 out of 36 (58 per cent.)
B. coli test	13 out of 80 (16 per cent.)	67 out of 86 (84 per cent.)	43 out of 80 (54 per cent.)	37 out of 86 (46 per cent.)
Indol test	None out of 8.	All 8.	1 out of 8.	7 out of 8.
Bile-salt glucose peptone test	11 out of 61 (18 per cent.)	50 out of 61 (82 per cent.)	31 out of 61 (51 per cent)	30 out of 61 (49 per cent.)
Neutral red broth test	7 out of 99 (7 per cent.)	92 out of 99 (92 per cent.)	39 out of 99 (39 per cent.)	60 out of 99 (60 per cent.)
Gas test (24 hours at 20° C.)	None out of 14	All 14 (100 per cent.)	8 out of 14 (57 per cent.)	6 out of 14 (43 per cent.)
B. enteritidis sporogenes test	4 out of 103 (3·8 per cent.)	99 out of 103 (96·1 per cent.)	20 out of 103 (19·4 per cent.)	83 out of 103 (80·5 per cent.)
Hendon Ducat Filter Effluent after sand filtration.				
Total number of bacteria (gelatine at 20° C.)	All of 4.	None of 4.	All of 4.	None of 4.
Total number of bacteria (agar at 37° C.)	All of 4.	None of 4.	All of 4.	None of 4.
B. coli test	30 out of 41 (73 per cent.)	11 out of 41 (27 per cent.)	40 out of 41 (98 per cent.)	1 out of 41 (2 per cent.)
Indol test	1 out of 4.	3 out of 4.	3 out of 4.	1 out of 4.
Bile-salt glucose peptone test	29 out of 37 (78 per cent.)	8 out of 37 (22 per cent.)	All of 37 (100 per cent.)	None of 37.
Neutral red broth test	35 out of 51 (69 per cent.)	16 out of 51 (31 per cent.)	49 out of 51 (96 per cent.)	2 out of 51 (4 per cent.)
Gas test (24 hours at 20° C.)	5 out of 7.	2 out of 7.	All of 7.	None of 7.
B. enteritidis sporogenes test	45 out of 52 (87 per cent.)	7 out of 52 (13 per cent.)	All of 52 (100 per cent.)	None of 52.

HORFIELD SEWAGE WORKS.

(Bristol City Corporation).

1. Situation of works - - - - - -	Ashley Down, about ½ mile from centre of Horfield.
2. Method of treatment - - - - -	Chemical precipitation and continuous flow subsidence, followed by percolating filters. (Stoddart's distributors used.)
3. Population draining to works during observations	About 2,500 (estimated average).
4. Water supply in gallons per head and whence obtained.	22 gallons; from the Bristol supply—a rather hard water.
5. Number of W.C.'s - - - - - -	About 250 W.C.'s and 5 latrines.
6. Sewerage system - - - - - -	Partially separate.
7. Average dry weather flow of sewage in gallons per 24 hours.	38,000.
8 Gallons of sewage per head per day - -	15·2.
9. Character of the sewage - - - - -	A domestic sewage with laundry refuse.
10. Period of observations - - - - -	November, 1902, to August, 1905.
11. Age of filters - - - - - -	About one year.
12. Amount of storm water treated on filters during observations.	All storm water entering sewers.
13. Total capacity of tanks in gallons - - -	27,200.
14. Total area of filters in yards (super) - -	(*a*) Shallow filter, 27·56. (*b*) Deep filter, 113·58.
15. Total cubic content of filters in yards (cube) -	(*a*) Shallow filter, 27·56. (*b*) Deep filter, 284.
16. Nature of filtering medium - - - -	Clinker (large) from local gas works.
17. Gallons of precipitation liquor treated per yard super per 24 hours. (All filters included).	Deep filter, in dry weather, 478. Shallow filter, 280.
18. Gallons of precipitation liquor treated per yard cube per 24 hours. (All filters included).	Deep filter, 190. Shallow filter, 280.
19. The final effluent is discharged into - -	A ditch, contributing to a stream called the "Boiling Wells."

FLOW OF SEWAGE.

The access of rain water to the sewers from the back roofs and yards of the houses results in large increases of flow at the sewage works during times of rain.

The main 9-inch outfall sewer, laid on rather a steep gradient, is capable of bringing sewage to the works at a rate of something like one million gallons per 24 hours, and as we have actually measured on several occasions, during times of comparatively small rainfall when heavy showers happened to fall upon wet ground, flows at the rate of between 600,000 and 700,000 gallons per 24 hours, it is possible that the full quantity of one million gallons per 24 hours is occasionally delivered to the works.

The actual amount brought to the works for a whole period of 24 hours during any ordinary wet day, however, is considerably less than this. The highest day's flow recorded during the gaugings amounted to 500,000 gallons, and was the result of a rainfall of 1·32 inches on wet ground. Flows of over 400,000 gallons per day were registered on several occasions.

Our measurements therefore lead us to conclude that, although the sewage occasionally arrives for treatment at a rate of something like 25 times the dry weather flow, it is exceptional for this rate to continue for any length of time. Probably the tanks and filters are seldom called upon to treat an actual volume of much more than 10 times the dry weather flow on any one day.

During the last four months of our observations—April, May, June, and July, 1905—Mr. Stoddart kept continuous daily records of the sewage flow at Horfield, and from these we have been able to form a very careful estimate of the dry-weather flow.

During dry weather, for the fortnight ending July 1st, 1905, the average daily flow was approximately 37,500 gallons, the highest day's flow being 42,220 and the lowest day's flow 34,630. The dry weather flow may be taken, therefore, to be approximately 38,000 gallons per day. This is corroborated by measurements made by ourselves in April and May, 1903, over a period of three weeks, though at this time the daily flows were rather higher, owing to some wet weather which prevailed at the commencement of the gauging.

With so many records available, we have also taken the opportunity to make an approximate estimate of the average daily flow at the works, by working out the daily flows throughout the whole of April, May, June, and July, 1905, and striking an average. The analysis of the figures obtained in this way is as follows:—

Average daily flow during 110 days,	62,346	gallons.	Rainfall,	8·688 inches.
Average daily flow during April, 1905,	91,560	,,	,,	2·707 ,,
,, ,, ,, May, 1905,	46,155	,,	,,	·064 ,,
,, ,, ,, June, 1905,	64,126	,,	,,	4·06 ,,
,, ,, ,, July, 1905,	48,338	,,	,,	·542 ,,
,, ,, ,, August 1905, (9 days only)	49,191	,,	,,	1·315 ,,

If the figure, 62,350 gallons per day, be taken as representing approximately the average daily flow at Horfield throughout the whole year, which it probably does, it follows that there is an increase of 64 per cent. on the dry weather flow, due to the admission into the sewers of rain water, subsoil water, &c.

Subsoil Water.—The flow of sewage appears never to be less at any time of the night than a rate of about 14,000 gallons per day, for in perfectly dry weather this same rate of flow is reached during the early hours of the morning each day. The figure appears to represent, therefore, a fairly constant flow of ground water or leakage from taps, or both.

In wet weather the night-flow remains very much swollen for several days after the rain has ceased.

On Diagram R are given some illustrations of the sewage flow at Horfield.

Diagram R.

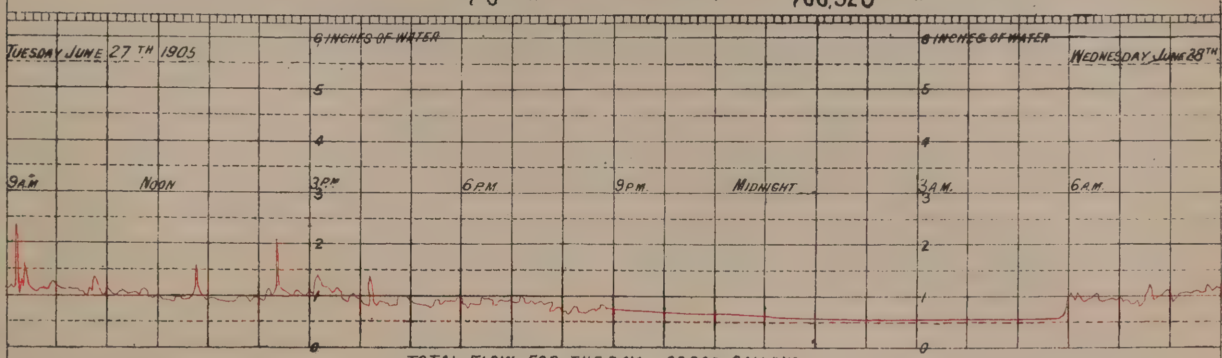
Diagrams showing flow of Sewage at Horfield

as falling over a Weir 12" wide.

Note:– Over a Weir 12" wide

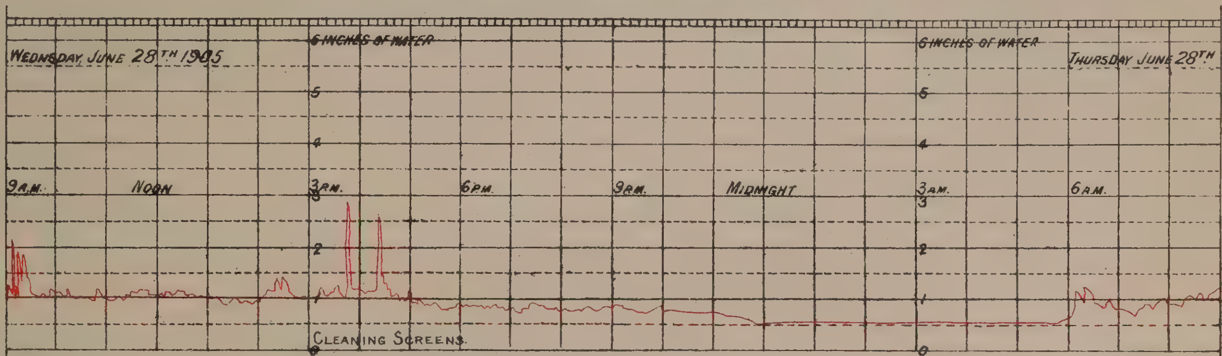
0·5 of an inch	= a rate of	14,830	gallons per 24 hours
1·0 inch	= " " "	41,760	" " " "
2·0 inches	= " " "	118,080	" " " "
5·0 "	= " " "	462,240	" " " "
6·0 "	= " " "	617,760	" " " "
7·0 "	= " " "	760,320	" " " "

RY DAY.
NFALL NIL.



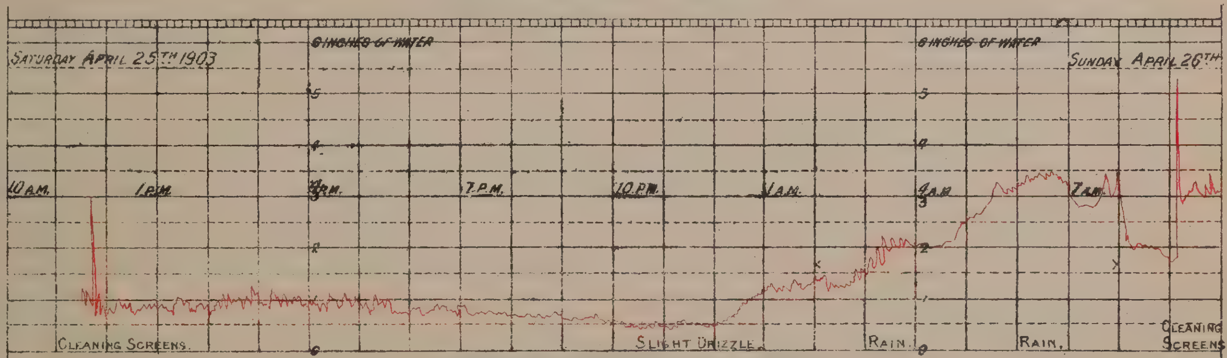
TOTAL FLOW FOR THE DAY – 43800 GALLONS

Y DAY.
FALL NIL.



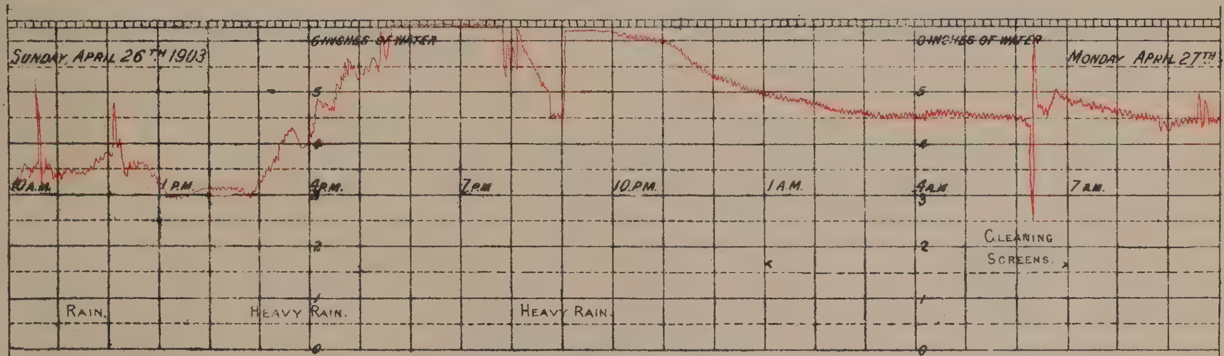
TOTAL FLOW FOR THE DAY = 43,550 GALLONS

T OF A STORM
LD.
DAY.
0·90 INCH.
OUND.



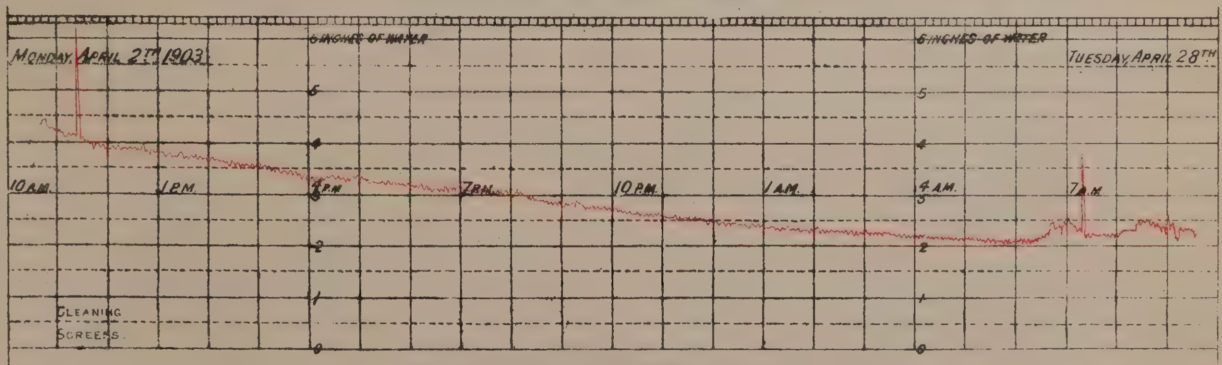
TOTAL FLOW FOR THE DAY = 78,750 GALLONS.

P DAY.
1·32 INCHES.



TOTAL FLOW FOR THE DAY. 485,500 GALLONS

P DAY.
0·03 INCH.



TOTAL FLOW FOR THE DAY = 226,600 GALLONS.

Waller & Graham Ltd Litho London.

Crude Sewage.—Three sets of hourly samples of crude sewage and three chance samples were examined chemically. The hourly samples, Nos. **3,149**, **3,151** (2) and **3,154**, extending over the usual three days, were drawn in the middle of May, **1903**, and represented practically a dry-weather flow. At the same time a sample of weak night-sewage, No. **3,155**, was taken. They gave the following results:—

	Parts per 100,000.	Average.	Number of Estimations.	No. 3,155. Weak Night Sewage.
Ammoniacal Nitrogen	(3·68 to 3·87)	3·80	(3)	—
Albuminoid Nitrogen	(0·85 to 1·21)	1·02	(3)	—
Total Organic Nitrogen	(1·97 to 2·40)	2·19	(3)	—
Oxidized Nitrogen (approx.)	(0·57, 0·45 and 0·0)	0·34	(3)	0·25 approx.
Total Nitrogen	(5·82 to 6·45)	6·24	(3)	—
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(2·08 to 3·63)	2·93	(3)	—
" " " " *in 4 hours*	(7·41 to 11·08)	9·39	(3)	0·91
Chlorine	(6·74 to 7·46)	7·00	(3)	4·18
Solids in Suspension	(21·0 to 49·0)	35·6	(3)	—
Solids by Centrifuge (vols.)	(174·0 to 384·0)	265·0	(3)	—
Ratio of Solids in Suspension to Centrifuge Solids	(1 : 7·0 to 1 : 8·3)	1 : 7·7	(3)	—
"Cellulose" (by alkali, acid, and ether)	(2·88 to 6·66)	4·66	(3)	—
Ratio of "Cellulose" to Solids in Suspension	(1 : 7·1 to 1 : 7·4)	1 : 7·3	(3)	—
Incubator Test (by smell)				?

The above figures show the Horfield sewage to be one of about average strength, perhaps rather under average, but with very varying amounts of suspended solids (of a rather flocculent character). As regards nitrogenous matter, the three sets were very uniform. The first two had each about **0·5** part of oxidized nitrogen, indicating the presence of appreciable quantities of subsoil water.

The sample of weak night-sewage was very weak indeed, with only a faint sea-weed smell when analysed; it almost withstood incubation, no doubt because of its subsoil water.

Besides the above sets of hourly samples, three chance samples of sewage, Nos. **3,137**, **3,140**, and **3,622**, were examined. All of these were drawn in very wet weather in April and May, **1903**, and March, **1905**.

They gave the following results:—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(2·64 approx. and 1·58)	—	(2)
Albuminoid Nitrogen	(0·54)	—	(1)
Oxidized Nitrogen	(0·30 approx. to 0·62 approx.)	0·46	(3)
Total Nitrogen	(3·84 and 3·76)	—	(2)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(0·63 to 2·29)	1·41	(3)
" " " " *in 4 hours*	(1·58 to 5·68)	4·10	(3)
Solids in Suspension	(21·8 and 20·7)	—	(2)
Solids by Centrifuge (vols.)	(26 to 152)	91·0	(3)
Ratio of Solids in Suspension to Centrifuge Solids	(1 : 4·9 and 1 : 7·3)	—	(2)

The middle sample of these was but little stronger than the weak sample of night sewage, No. 3,155, while the other two were about half the strength of the hourly sets of samples. The three were noted at the time of analysis as having respectively a fishy smell, practically no smell, and a slight fishy smell, *i.e.*, they could hardly be said to smell of sewage (they failed, however, to withstand incubation). The conclusion is therefore justified, we think, that the substances which give rise to the characteristic odour of sewage are among the first to be oxidized by nitrate.

The comparatively heavy rainfall of the West of England causes the Horfield sewage to be very dilute at times.

On the other hand, the sewage in storm times can be exceedingly strong. Since the systematic observations at Horfield were concluded, the manager of the works has sent at our request one or two further samples. These were examined in duplicate, *i.e.* (*a*) with all their solids, and (*b*) after two hours' settlement in the laboratory. The results are interesting, so the figures of analysis may be given in detail here. It will be seen that the settlement of solids effected in the two hours was very marked in samples 1 and 3, but even then the liquids remained highly impure. Sample No. 3 was an altogether abnormal one; it looked as if the sample happened to be drawn just as the contents of a urinal—not greatly diluted—had reached the works. In the analysis of this sample the free ammonia was given off practically indefinitely. In two of the samples the dilutions made for absorption of dissolved oxygen were insufficient.

Parts per 100,000.	No. 1. Crude Sewage. Drawn Monday, March 27th, 1905, 9 a.m. Raining from 2 p.m. on Sunday. Flow 2 inches for some hours over 12 inch weir and still 2 inches at time of drawing.		No. 2. Crude Sewage. Drawn Monday, March 27th, 1905, 11 a.m. Flow 2 inches over 12 inch weir.		No. 3. Crude Sewage. Drawn Tuesday, June 13th, 1905, 8 a.m. Heavy rain at 3·30 p.m. on 12th, which lasted for the 18 hours previous to taking the samples. Flow over 12 inch weir averaged 2½ inches for these 18 hours.	
	Original.	Settled 2 hours.	Original.	Settled 2 hours.	Original.	Settled 2 hours.
Ammoniacal Nitrogen					21·7+x*	19·5+x*
Albuminoid Nitrogen					Not done	Not done
Total Nitrogen	10·41		8·21		130·25	127·73
"Oxygen absorbed" at 27° C. *at once*	7·34	2·28	3·93	2·19	13·82	11·66
"Oxygen absorbed" at 27° C. *in 4 hours*	30·44	8·42	18·73	12·41	57·37	53·78
Chlorine					33·10	
Dissolved Oxygen taken up in 24 hours at 18°C.	28·17	19·3+x*	19 8+x	9·4+x	39·4+x	32·7+x
Incubator test (by smell)	—	—	—	—		
Solids in suspension	171·5 < 65·7 vol. / 105·8 non vol.		37·1 < 31·8 vol. / 5 3 non vol.		56·9 < 19·3 vol / 37·6 non vol	5·3 < 3·2 / 2·1
Solids by centrifuge (vols.)	923·0	126·5	304·0	91·4	684·0	67·0
Ratio of solids in suspension to centrifuge solids.	1 : 5 4		1 : 8·2		1 : 12·0	1 : 12·6

Bacteriological Notes.—Six samples were examined bacteriologically. Sample 3,155 (weak night-sewage) yielded a negative result with ·0001 c.c. with the neutral red broth test, and a negative result with the B. enteritidis sporogenes test with ·01 c.c. All the

* The signs +x mean "more than"; thus 19·3+x means "more than 19·3."

other samples yielded positive results with the neutral red broth test with ·00001 c.c. (100,000 per c.c.). As regards the B. enteritidis sporogenes test, one sample contained 10, three samples 100, and one sample 1,000 spores of this anoerobe, per c.c.

Description of the Sample.	Number of B Coli (or gas-forming coli-like Microbes).	B.S.=Bile Salt Glucose Peptone Test. N.R.=Neutral Red Broth Test. In.=Indol Test. L.P.M.=Lactose Peptone Milk Test.	B. Enteritidis Sporogenes Test.	Remarks.
3140. Horfield Crude Sewage. 3/5/03.	—	100,000 N.R.	10 not 100	
3149. Horfield Crude Sewage. 12/5/03.	—	100,000 N.R.	100 not 1,000	
3151. Horfield Crude Sewage. 13/5/03.	—	100,000 N.R.	100 not 1,000	
3154. Horfield Crude Sewage. 14/5/03.	—	100,000 N.R.	1,000 not 10,000	
3155. Horfield Crude Sewage. 14/5/03. [Weak night sewage.]	—	1,000 not 10,000 N.R.	10 not 100	
3622. Horfield Crude Sewage. 9/3/05.	10,000 (– indol) (– clot)	100,000 B.S. 100,000 N.R.	100 not 1,000	

SCREENS.

Immediately upon issuing from the outfall sewer, the sewage passes through a half-inch screen. This is, as a rule, raked once a day, and the screenings are used for manure upon the works.

PRECIPITATION TANKS.

Number - - - - -	3.
Size of each - - - -	12 feet diameter, 18 feet deep.
Capacity of each - - -	9,067 gallons.
Total capacity - - -	27,200 gallons.

Construction.—The tanks are constructed of brick and cement upon the Dortmund plan, being cylindrical to a depth of about 10 feet, and conical from there to the bottom. They are sunk in the ground. The sewage is delivered at the top of the cone (that is, at a depth of 10 feet) through a pipe which runs down through the centre of the tank, and is spread at the outlet by a bonnet reaching almost to the cone. The tank liquor issues from the tank over a circular sill extending round the whole of the retaining wall at the top.

Flow through.—With a dry weather flow of 38,000 gallons per day, the flow through would be once in 17 hours at the rate of ·12 inches per minute.

Precipitant.—The precipitant used is Alumino-ferric. It is added to the sewage, as this flows to the tanks, by dripping water upon it when placed in a box which has a false bottom. In this way the amount added can be regulated according to the strength of the sewage, and indeed, in some measure it regulates itself, for, owing to the fact that fresh precipitant is put into the box each morning, the water running over a greater surface of precipitant dissolves more of it at this time, when the sewage is strong, than it does towards night, when the precipitant is almost all dissolved away.

The quantity used is about 5 grains per gallon, which is equivalent to about 4½ tons per year.

Working.—The tanks are used in parallel, and the flow through them is a continuous one. They are cleaned out every other day.

Sludging.—In the apex of the cone in each tank, a valve connects with a sludge pipe which is brought up to within 18 inches of the water level in the tank, and is then carried to a sludge sump, 10 feet by 5 feet by 5 feet deep, situated close by. On opening this valve, the sludge lying in the cone is forced out by the 18 inch head of water and delivered to the sludge sump. In order to remove sludge from the tanks, therefore, it is only necessary, under ordinary conditions, to lower the water level in the tank slightly, and there is consequently no need for complete emptying.

It may be said, however, that on a good many occasions the sludge has been found in practice to be too thick for the 18-inch head, and in consequence the sludge main has been converted into a syphon, in order to facilitate the drawing off of the sludge.

As a general rule, about 1,200 cubic feet of liquid sludge are removed from the 3 tanks every week. In the sludge sump the sludge is mixed with lime and then pumped up to the presses, which produce 4½ to 5 tons of pressed cake (containing 7 per cent. to 10 per cent. of lime) per week. This is easily disposed of to farmers, who are allowed to take it free.

The strongly alkaline press water which is pumped back into the tanks has a most pungent smell, and is conseqnently liable to give rise to nuisance; but otherwise the operation is conducted without nuisance.

Precipitation Liquor.—Three sets of hourly samples and thirteen chance samples of precipitation liquor were examined chemically. The *hourly samples*, Nos. 3,149A, 3151A and 3154A, were drawn in the middle of May, 1903, at the same time as the hourly samples of sewage, when the weather was practically dry. They gave the following results :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(2·59 to 3·94)	3·31	(3)
Albuminoid Nitrogen	(0·23 to 0·38)	0·32	(3)
Total Organic Nitrogen	(0·32 to 0·92)	0·59	(3)
Oxidized Nitrogen	(0·0 to 0·75)	0·37	(3)
Total Nitrogen	(3·66 to 4·86)	4·27	(3)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(0·64 to 0·94)	0·82	(3)
" " " " " " " *in 4 hours*	(2·66 to 3·48)	3·12	(3)
Chlorine	(5·48 to 6·50)	6·11	(3)
Solids in suspension	(2·04 to 3·34)	2·51	(3)
Solids by centrifuge (vols.)	(13·0 to 23·0)	19·0	(3)
Ratio of Solids in Suspension to centrifuge Solids	(1 : 3·9 to 1 : 11·3)	1 : 8·2	(3)

In appearance these hourly samples of precipitation liquor were slightly turbid, but they contained, on the average, only 2·5 parts of (flocculent) suspended solids. In two out of the three there was still an appreciable amount of oxidized nitrogen, and it is noteworthy that those two still had a clean smell on the day of analysis. The precipitation effected in dry weather is therefore good, and the filters are only called upon to treat a somewhat weak liquor.

As compared with the hourly samples of sewage, the above hourly samples of precipitation liquor show the following reduction in figures :—

Calculated on :—	Reduction.
Total Nitrogen	32 per cent.
Albuminoid Nitrogen	69 „
Total Organic Nitrogen	73 „
"Oxygen absorbed" *at once*	72 „
„ „ *in 4 hours*	67 „
Solids in suspension	93 „
Solids by centrifuge (vols,)	93 „

The thirteen chance samples of precipitation liquor examined were numbered 3067, 3080, 467, 3122, 3137A, 3139, 3141, 3413A, 3545, 3574, 3577, 778, and 3623. These include nine ordinary chance and four experimental chance samples. They were drawn between November, 1902, and March, 1905, between 10.30 a.m., and 4.45 p.m., but—excepting for one sample in August—all of them in the cooler months, from November to May. Five were taken in dry weather, three in dry weather following wet, and five in wet weather.

The following results were obtained :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(1·78 to 5·12)	3·66 approx.	(4)
Albuminoid Nitrogen	(0·38 to 0·74)	0·52	(3)
Oxidized Nitrogen	(0·0 to 0·44 approx.)	0·13 approx.	(5)
Total Nitrogen	(3·67 to 10·46)	5·76	(10)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(0·58 to 2·46)	1·32	(13)
„ „ „ „ *in 4 hours*	(3·54 to 7·28)	4·62	(12)
Chlorine	(6·72 to 9·70)	7·81	(3)
Suspended Solids	(11·3, 5·5 and 20·4)	—	(3)
Solids by Centrifuge (vols.)	(26·0 to 108·5)	48·7	(13)

The chance samples of precipitation liquor were more or less turbid, usually with light-brown flocculent matter, and four of them still had a more or less clean smell on the day of analysis. If we exclude a few strong samples, they were fairly uniform in composition, though of course not nearly so uniform as the hourly samples, but—taking them all over—they were distinctly stronger than the latter. In respect of suspended matter they were distinctly inferior to the hourly samples, but it is very noticeable that the increase in solids took place during stormy weather. Reckoning approximately from the centrifuge figures (for only three gravimetric estimations of suspended solids were made), the chance samples of precipitation liquor contained about twice as much suspended matter as the hourly samples. The effect of dry weather in giving stronger samples is well marked in the case of Nos. 3,574 and 778, the respective figures for total nitrogen in these being 10·14 and 10·46.

Compared with the hourly samples of sewage, tht chance samples of precipitation liquor show the following reduction in figures.

Calculated on :—	Reduction.
Total Nitrogen - - - - - - - - - - - - -	9 per cent.
"Oxygen absorbed" *at once* - - - - - - - - - - -	55 ,,
,, ,, *in 4 hours* - - - - - - - - -	51 ,,
Solids by Centrifuge (vols.) - - - - - - - - - - -	82 ,,

Bacteriological Notes.—Thirteen samples were examined bacteriologically. The B. coli test and presumptive tests for B. coli yielded positive results with from ·0001 c.c. to ·00001 c.c. (10,000 to 100,000 per c.c.). As regards the B. enteritidis sporogenes test, two samples contained 10, nine samples 100, and two samples 1,000 spores of this anaerobe per c.c. Sample 467 contained 168,000 microbes per c.c. (agar at 37° C).

Description of the Sample.	Number of B. Coli (or gas-forming Coli-like Microbes).	B.S.=Bile-Salt Glucose Peptone Test. N.R.=Neutral Red Broth Test. In.=Indol Test. L.P.M.=Lactose Peptone Milk test.	B. Enteritidis Sporogenes Test.	Remarks.
3067. Horfield precipitation liquor. 27/11/02.	100,000 (– indol) (– clot)	10,000 not 100,000 B.S. 100,000 In. 100,000 L.P.M.	100 not 1,000	"Gas" test + ·01 c.c. (24 hours at 20° C.).
3080. Horfield precipitation liquor. 20/12/02.	—	100,000 B.S. 100,000 N.R. 100,000 L.P.M.	10 not 100	"Gas" test + ·01 c.c. (24 hours at 20° C.).
467. Horfield precipitation liquor. 13/1/03.	100,000 (+ indol) (+ clot)	10,000 not 100,000 NR. 100,000 In.	100 not 1,000	168,000 microbes per c.c. (agar at 37° C.).
3122. Horfield precipitation liquor. 12/3/03.	—	10,000 not 100,000 N.R.	100 not 1,000	
3141. Horfield précipitation liquor. 3/5/03.	—	100,000 N.R.	100 not 1,000	
3149A. Horfield precipitation liquor. 12/5/03.	—	100,000 N.R.	100 not 1,000	
3151A. Horfield precipitation liquor. 13/5/03.	—	100,000 N.R.	10 not 100	
3154A. Horfield precipitation liquor. 14/5/03.	—	10,000 not 100,000 N.R.	100 not 1,000	
3413A. Horfield precipitation liquor. 3/3/04.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R.	100 not 1,000	
3545. Horfield precipitation liquor. 19/8/04.	100,000 (– indol) (+ clot)	100,000 B.S. 100,000 N.R.	100 not 1,000	
3574. Horfield precipitation liquor. 30/11/04.	10,000 not 100,000 (– indol) (+ clot)	10,000 not 100,000 B.S. 10,000 not 100,000 N.R.	100 not 1,000	
778. Horfield precipitation liquor. 4/1/05.	—	100,000 B.S. 100,000 N.R.	1,000 not 10,000	
3623. Horfield precipitation liquor. 9/3/05.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 B.S. 100,000 N.R.	1,000 not 10,000	

FILTERS.

Deep Filter

Size - - - -	43 feet 6 inches by 23 feet 6 inches.
Area - - -	113·58 square yards.
Depth of material - -	7 feet 5 inches.
Cubic contents - - -	284 cube yards.
Material - - -	Gas works clinker, graded as nearly as possible to 3 inches diameter.

(The grading of the material in both the Stoddart filters at Horfield was done by means of washing and not by riddling, the broken material being thrown into water and then lifted out again with a wide pronged fork. This method is put forward by Mr. Stoddart as being greatly preferable to the ordinary riddling, in that it removes all the fine clinker adhering to the larger lumps.)

Construction.—The material is laid to a depth of 7 feet 5 inches on a concrete bottom, which falls in three directions (one in thirty six each way). It is composed of a layer of large lumps (6 inches diameter) at the bottom, about 6 inches deep, and pieces of about 3 inches diameter above. It is kept in position on one side by a wall carrying the main feed channel and on the opposite side by a wall carried halfway up the side of the filter, but open at the bottom, as well as by the brick piers which carry the branch distributing channels. These two sides are perpendicular.

The other two sides are constructed of large pieces of clinker, carried up the side of the filter with a slight batter.

The filter is therefore shut in on one side, but is completely open on two sides and practically open on the third. It is partly below the level of the ground and partly above it.

Distribution.—The tank liquor is distributed over the deep filter by means of 42 Stoddart trays, arranged in 6 rows of 7 each, each tray being fed on both sides from iron channels carried on brick piers.

Very briefly described (for fuller description see note below*) the Stoddart distributor consists of a galvanized iron sheet, bent into a number of V-shaped corrugations (ridge and furrow arrangement); the top of each ridge is perforated with a number of holes, while an equal number of nails hang opposite to these from the bottom of the furrows. When the liquor to be treated, therefore, flows into each channel on the tray, it rises

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* *Mr. Stoddart's description of the Distributor.*—The Stoddart Distributor consists of a gutter provided along the bottom on the under side with a series of dependent drip-points. On filling with liquid, the latter overflows the margins of the gutter, and, on reaching the nearest drip-point, falls upon the surface of the filter in a succession of drops.

The gutter is made V-shaped in section, partly to secure the maximum of rigidity, partly to direct the liquid towards the drip-points.

Several distributor gutters are conveniently united together to form a distributor sheet, provision being made for the passage of the liquid from the upper to the under surface by a number of openings between the gutters. These openings may be of any size, as they do not determine the comminution of the liquid, this being effected by the drip-points.

The distributors are connected with the sewage tank by means of specially designed cast iron channels (supply channels) provided with recesses to form water-tight joints with the end of the distributor, and the whole apparatus is supported by adjustable chairs carried on iron Tees, by which means levelling is readily effected.

When the system of channels and distributors is in action, the liquid stands at one uniform depth throughout, whatever quantity of liquid is being applied, and the exit is so free and unimpeded that it is immediately disposed of. Hence the distribution is completely independent of variations in the rate of flow, the only difference observable being in the rapidity of the dropping. Moreover, as the comminution of the liquid is effected in the interval between the margins of the distributor gutters and the drip-points below (scarcely more than one inch), practically the whole of the fall is utilised in the filter body.

till the channel is full, and then overflowing continuously through the holes on the ridge and running down on the under side, finds its way to the dependent nails and so drips on to the filtering material.

Spaces measuring about six feet by one foot separate every two trays.

Age of Filter.—The deep filter was started in September, 1901.

Working.—The filter works continuously night and day, and is never rested. It deals with all the variations of the sewage flow.

Amount of Precipitation Liquor treated upon the Deep Filter.—On the basis of an average daily flow equivalent to 62,350 gallons per day, the following figures represent the average quantity treated per 24 hours upon the deep filter at Horfield during the first part of our observations :—

Per square yard, per 24 hours - - - - - -	478 gallons.
Per cube yard per 24 hours - - - - - -	190 ,,

Deep Filter Effluents.—Three sets of hourly samples and 17 chance samples were examined chemically. The hourly samples, Nos. 3,151, 3,153 and 3,157, were drawn at the same time as the hourly samples of sewage (and of precipitation liquor) and represented practically a dry-weather flow. Excepting that No. 3,151 contained less ammonia than the others, all three sets were remarkably uniform in composition. They gave the following results :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - - - - - -	(1·28 to 1·97)	1·69	(3)
Albuminoid Nitrogen - - - - - - - - -	(0·15 to 0·15)	0·15	(3)
Oxidized Nitrogen - - - - - - - -	(1·98 ap. to 2·39 ap.)	2·19 ap.	(3)
(including Nitrous Nitrogen) - - - - - -	(0·14 to 0·19)	0·17	(3)
"Oxygen absorbed" at 27° C. (80° F.) *at once* - - -	(0·60 to 0·63)	0·62	(3)
,, ,, ,, ,, *in 4 hours* - -	1·55 to 1·66)	1·60	(3)
Solids in suspension - - - - - - - - -	(3·64 to 3·66)	3·65	(3)
Solids by centrifuge (vols.) - - - - - - -	(32·0 to 37·0)	34·0	(3)
Ratio of solids in suspension to centrifuge solids - -	(1 : 8·7 to 1 : 10·2)	1 : 9·2	(3)
Incubator test (Scudder) - - - - - - - -	3 +		(3)
Incubator test (by smell) - - - - - - - - -	3 +		(3)
Smell when drawn - - - - - - - - - -	3 +		(3)
Smell when analysed - - - - - - - - - -	3 +		(3)

The above effluents contained appreciable quantities of flocculent brown-coloured solids, but they filtered to perfectly clear liquids of a slightly brownish tint. They were all well nitrated, were inoffensive as regards smell, both when drawn and when analysed, and all of them easily withstood incubation. They may be looked upon as effluents of very fair quality, and they would have been still better had it been possible to separate out some of their flocculent solids.

Compared with the hourly samples of sewage and of precipitation liquor, they show the following reduction in figures :—

Calculated on :	Sewage.	Precipitation Liquor.
Albuminoid Nitrogen - - - - - -	85 per cent. reduction	53 per cent. reduction
"Oxygen absorbed" *at once* - - - - -	79 ,, ,,	24 ,, ,,
,, ,, *in 4 hours* - - - -	82 ,, ,,	49 ,, ,,
Solids in suspension - - - - - -	90 ,, ,,	+45 ,, ,,
Solids by centrifuge (vols.) - - - - -	86 ,, ,,	+79 ,, ,,

Deep Filter Effluents (*Chance Samples*).—The 17 chance samples of deep filter effluent examined were made up of 12 ordinary samples drawn between November 27th, 1902, and October 7th, 1904, and five experimental samples which will be discussed separately. The 12 ordinary samples were numbered 3068, 3081, 468, 3122B, 3137A_1, 3139A, 3141A, 3276, 3341, 3415B_2, 3547, and 3552. Excepting No. 3547, taken in August, 1904, they were all drawn in the cooler months of the year, *i.e.*, between October and May. Five of them were drawn in dry weather, five in dry weather following wet, and two in wet or stormy weather.

The following figures were obtained on analysis :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - - - -	(1·14 to 3·74)	2·26	(8)
Albuminoid Nitrogen - - - - - - - -	(0·16 to 0·35)	0·23 †	(7)
Oxidized Nitrogen - - - - - - -	(0·50 ap. to 1·85)	1·19 ap.	(12)
(containing Nitrous Nitrogen - - - - - -	(0·02 to 0·24)	0·12	(12)
Total Organic Nitrogen - - - - - - -	(0·21 to 1·38)	0·67	(4)
Total Nitrogen - - - - - - - - - -	(3·23 to 6·25)	4·76	(5)
"Oxygen absorbed" at 27° C. (80° F.) *at once* - - -	(0·43 to 1·05)	0·69	(12)
,, ,, ,, ,, *in 4 hours* - - -	(1·28 to 4·51)	2·47	(12)
*Dissolved Oxygen taken up in 24 hours at about 18°C. -	(0·14 to 0·87)	0·54 ap.	(10)
Chlorine - - - - - - - -	(4·66 to 9·46)	6·91	(4)
Solids in suspension - - - - - - - -	(3·10 to 16·25)	7·00	(8)
Solids by centrifuge (vols.) - - - - - - -	(36·0 to 180·0)	71·0	(12)
Ratio of solids in suspension to centrifuge solids - -	(1 : 7·8 to 1 : 18·7)	1 : 12·2	(8)
Incubator Test (Scudder) - - - - - - - -	8 + 4 —		(12)
Incubator Test (by smell) - - - - - - - -	12 +		(12)
Smell when drawn - - - - - - - - - -	8 + 3 ?		(11)
Smell when analysed - - - - - - - - -	11 + 1 ?		(12)
c.c. per litre *Oxygen in solution - - - - -	(0·0 to 4·0)	2·7 ap.	

* These figures are to be taken as approximate only. Two-thirds of the estimations were made by the Copper Chloride method and one-third only by the Manganese method.

† This figure may possibly be a little too high.

In appearance and character these chance samples of Deep Filter effluent were like the hourly samples, *i.e.*, the liquid was clear or almost clear, with varying quantities of brownish flocculent suspended solids. It will be seen that 8 out of 11 had a clean smell when drawn, and 11 out of 12 a clean smell when analysed, while the whole twelve samples withstood incubation. The oxidized nitrogen varied between 0·5 and 1·8 parts and averaged 1·2 parts—a fair amount. The average (approximate) figure for absorption of dissolved oxygen is not very high (about 0·5 part). As was to be expected from the varying quantities of liquid treated on the filter, the solids in suspension in the effluents varied greatly in amount (between 3 and 16 parts), but the average figure for all of them—arrived at partly from the centrifuge readings—would be from 6 to 7 parts. The effluents are, therefore, to be looked upon as satisfactory, except as regards the suspended solids. These require to be separated as far as possible, either by settlement or filtration. Had the solids been separated, these effluents would have been of very good quality. It is a little difficult to discriminate between wet and dry weather effluents, in this instance, as regards quality. Nitrate was higher in the dry-weather samples; wet weather dilutes the organic matter in solution, but brings more solids into the filters and washes more solids out of them.

The figures of analysis of these chance samples of deep filter effluent are not so good on the whole as those of the hourly samples, oxidation not having gone so far; on the other hand, the difference is partly due to the larger quantity of suspended solids in the chance samples.

Compared respectively (*a*) with the hourly samples of sewage; (*b*) the hourly samples of precipitation liquor; and (*c*) the nine chance samples of precipitation liquor drawn between November 27th, 1902, and August 19th, 1904, *i.e*, within practically the same limits of time as the chance samples of Deep Filter Effluent, these chance samples show the following reduction in figures:—

Calculated on :	Sewage.	Precipitation Liquor.	
	Hourly Samples.	Hourly.	Chance Samples.
Ammoniacal Nitrogen - - - -	40 per cent. reduction	32 per cent.	—
Albuminoid Nitrogen - - - -	77 „ „	28 „	—
"Oxygen absorbed" *at once* - - -	76 „ „	16 „	48
„ „ *in 4 hours* - -	74 „ „	21 „	47
Solids in suspension - - - -	80 „ „	+160 approx.	—
Solids by centrifuge (vols.) - - -	73 „ „	+270 „	+46 approx.

Bacteriological notes.—Eighteen samples were examined bacteriologically. The B. coli test and presumptive tests for B. coli yielded positive results with from ·01 c.c. to ·00001 c.c. (100 to 100,000 per c.c.). Usually, however, the results varied from ·001 c.c. to ·0001 c.c. (1,000 to 10,000 per c.c.). Sample 468 contained 9,000 microbes per c.c. Sample 467, which was a comparative sample of precipitation liquor, contained 168,000 bacteria in 1 c.c. The percentage reduction in the case of Sample 468 was 94 per cent. As regards the B. enteritidis sporogenes test, one sample contained 1; four samples contained 10; eleven samples 100; and two samples 1,000 spores of this anaerobe per c.c. It should be noted that sample 3,563 and later samples were collected after the rates of flow in connexion with the deep and shallow filters had been adjusted in the manner described in the text of the report.

Description of the Sample.	Number of B. coli (or gas-forming coli-like microbes).	B.S.=Bile salt glucose peptone test. N.R.=Neutral red broth test. In Indol test. L.P.M.=Lactose peptone milk test.	B. enteritidis sporogenes test	Remarks
3068. Horfield deep filter effluent, 27/11/02.	1,000 not 10,000 (— indol) (+ clot)	1,000 not 10,000 B.S. 100 not 1,000 N.R. 100 not 1,000 I.N. 1,000 not 10,000 L.P.M.	10 not 100	"Gas" test + 1 c.c. (24 hours at 20°C).
3081. Horfield deep filter effluent, 20/12/02.	—	100 not 1,000 B.S. 100 not 1,000 N.R. 100 not 1,000 L.P.M.	10 not 100	"Gas" test + 1 c.c. (24 hours at 20°C).
468. Horfield deep filter effluent, 13/1/03.	10,000 not 100,000 (+ indol) (+ clot)	1,000 not 10,000 N.R. 1,000 not 10,000 I.N.	100 not 1,000	9,000 microbes per c.c. (agar at 37° C).
3122B. Horfield deep filter effluent, 12/3/03.	—	10,000 not 100,000 N.R.	1,000 not 10,000	
3137A[1]. Horfield deep filter effluent, 26/4/03.	—	10,000 not 100,000 N.R.	100 not 1,000	
3141A[1]. Horfield deep filter effluent, 3/5/03.	—	1,000 not 10,000 N.R.	100 not 1,000	
3151([1]). Horfield deep filter effluent, 12/5/03.	—	1,000 not 10,000 N.R.	10 not 100	
3153. Horfield deep filter effluent, 13/5/03.	—	100 not 1,000 N.R.	1 not 10	
3157. Horfield deep filter effluent, 14/5/03.	—	100 not 1,000 N.R.	10 not 100	
3276. Horfield deep filter effluent, 28/10/03.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R.	100 not 1,000	
3341. Horfield deep filter effluent, 17/12/03.	—	1,000 not 10,000 N.R.	100 not 1,000	
3415B[2] Horfield deep filter effluent, 3/3/04.	1,000 not 10,000 (+ indol) (+ clot)	1,000 not 10,000 N.R.	100 not 1,000	
3547. Horfield deep filter effluent, 19/8/04.	100,000 (— indol) (+ clot)	100,000 B.S. 10,000 not 100,000 N.R.	100 not 1,000	
3552. Horfield deep filter effluent, 7/10/04.	100,000 (— indol) (— clot)	100,000 B.S. 100,000 N.R.	100 not 1,000	
3563. Horfield deep filter effluent, 16/11/04.	10,000 not 100,000 (— indol) (+ clot)	10,000 not 100,000 B.S. 100,000 N.R.	100 not 1,000	
3575 Horfield deep filter effluent, 30/11/04.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 B.S. 10,000 not 100,000 N.R.	1,000 not 10,000	
779. Horfield deep filter effluent, 4/1/05.	1,000 not 10,000 (+ indol) (+ clot)	1,000 not 10,000 B.S. 10,000 not 100,000 N.R.	100 not 1,000	
3625. Horfield deep filter effluent. 9/3/05.	100,000 (+ indol) (+clot)	100,000 B.S. 100,000 N.R.	100 not 1,000	

SHALLOW FILTER.

Size - - - - - -	19 feet 1 inch by 13 feet.
Area - - - - - -	27·56 square yards
Depth of material - - - -	3 feet.
Cubic contents - - - - -	27·56 cube yards.
Material - - - - -	Gas-works clinker, graded as nearly as possible to 3 inches diameter.

(The grading of the material for this filter was carried out in the same way as that of the material for the deep filter, that is to say, by washing instead of riddling.)

Construction.—The material is carried up from a concrete bottom to a height of three feet. It is kept in position on the inlet side by a wall; on the opposite side to this, by large pieces of clinker, built perpendicularly; and on the other two sides by large pieces of clinker built with a slight batter. The filter is therefore open on three sides. It is built in a tank which had originally been used for another purpose, and is below the level of the retaining walls of this tank.

Distribution.—The distribution on the shallow filter is by means of the Stoddart trays, of which there are nine in three rows of three trays each, fed by one channel at the inlet end of the filter. The trays rest on cement bars built on the material. In this case (differing from the plan of filling the trays on the deep filter), the tank liquor, in order to reach the far end of the bed, has first to pass over two trays, and, in consequence the distribution is not as good as it should be. There are also no proper levelling arrangements to the trays. These defects were pointed out to us at the commencement of the observations, and it is not fair, therefore, that the distribution effected by the trays on the shallow filter should be taken as typical of the method. The point must also be specially borne in mind when the work of the two filters is compared.

The trays are cleaned out about once a month, the operation taking one man about half-an-hour.

Age of Filter.—The shallow filter at Horfield was started in September, 1901.

Working.—The filter works continuously night and day, and is never rested. It deals with considerable variations in the flow of sewage.

Amount of Precipitation Liquor treated upon the Shallow Filter.—On the basis of an average daily flow of sewage equivalent to 62,350 gallons per day, the average rate of treatment upon the shallow filter during the first part of our observations was

Per square yard per 24 hours	- - - -	280 gallons.
,, cube ,, 24 ,,	- - - -	280 ,,

Shallow Filter Effluents.—Three sets of hourly samples, Nos. 3150, 3152, and 3156, in addition to 14 chance samples, were examined chemically. The hourly samples were drawn at the same time and under the same conditions as the hourly samples of sewage, precipitation liquor, and deep filter effluent, and represented practically a dry weather flow. Here, again, the first hourly set contained less ammonia than the other two, but the samples were otherwise very uniform, though not quite so uniform as the hourly sets of deep filter effluent.

The following results were obtained :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - - - - -	(1·41 to 2·64)	2·11	(3)
Albuminoid Nitrogen - - - - - - - -	(0·12 to 0·18)	0·15	(3)
Oxidized Nitrogen - - - - - - -	(2·10 ap. to 2·23 ap.)	2·16 ap.	(3)
(including Nitrous Nitrogen) - - - - - -	(0·43 to 0·55)	0·47	(3)
"Oxygen absorbed" at 27° C. (80° F.) *at once* - . -	(0·82 to 0·87)	0·85	(3)
,, ,, ,, ,, *in 4 hours* - - -	(1·98 to 2·58)	2·26	(3)
Solids in suspension - - - - - - - -	(2·16 to 2·60)	2·42	(3)
Solids by centrifuge (vols.) - - - - - - -	(24·0 to 31·0)	26·0	(3)
Ratio of solids in suspension to centrifuge solids - -	(1 : 11·1 to 1 : 12·0)	1 : 11·7	(3)
Incubator Test (Scudder) - - - - - - - -	3 +		(3)
Incubator Test (by smell) - - - - - - - -	3 +		(3)
Smell when drawn - - - - - - - - -	3 +		(3)
Smell when analysed - - - - - - - - -	3 +		(3)

The above shallow filter effluents were much the same in character and appearance as the corresponding effluents from the deep filter, and they contained rather less suspended solids. Like the latter, they were well nitrated, had an inoffensive smell both when drawn and when analysed, and withstood incubation. If, however, the figures of analysis be studied, it will be seen that they were throughout not of quite such good quality as the deep filter effluents; but this is not surprising, seeing that on the average the shallow filter was treating 1½ volumes per cubic yard for 1 volume treated on the deep filter. The actual volumes of precipitation liquor, per cubic yard, treated at the time, were :—

Deep filter - - - -	190	gallons.
Shallow filter - - - -	280	,,

Still, the shallow filter effluents were effluents of moderate or fair quality, though the oxidation of their organic matter was not carried so far as in the deep filter effluents.

Compared with the hourly samples of sewage and of precipitation liquor, they show the following reduction in figures :—

Calculated on :—	Sewage.	Precipitation Liquor.
Albuminoid Nitrogen - - - - - -	85 per cent. reduction	53 per cent. reduction
"Oxygen absorbed" *at once* - - - -	71 ,, ,,	+ 4 ,, ,,
,, ,, *in 4 hours* - - - -	76 ,, ,,	28 ,, ,,
Solids in suspension - - - - - -	93 ,, ,,	4 , ,,
Solids by centrifuge (vols.) - - - - -	90 ,, ,,	+ 37 ,, ,,

It will be noticed that the deep filter effluents contained *more* suspended solids than the precipitation liquor (3·65 as against 2·51 parts), while the shallow filter effluents had about an equal quantity (2·42 parts). No conclusions can, however, be drawn from this; regular analyses over a long period of time would be necessary.

Shallow Filter Effluents. Chance Samples.—The 14 chance samples of shallow filter effluents examined chemically were made up of 9 ordinary samples, drawn between December 20th, 1902, and October 7th, 1904, and 5 experimental samples; these latter will be discussed separately. The ordinary samples were numbered 3,082, 3,122A, 3,137A_2, 3,141A_2, 3,277, 3,342, 3,414B_1, 3,546, and 3,553. Two of them were drawn in dry weather, 5 in dry weather after wet, and 2 in wet or stormy weather. Again, excepting one sample drawn in August, 1904 (No. 3,546), they were all taken in the cooler months of the year, between October and May.

The following results were obtained on analysis:—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - - - - - -	(1·26 to 4·28)	2·61	(6)
Albuminoid Nitrogen - - - - - - - - -	(0·16 to 0·44)	0·31	(5)
Oxidized Nitrogen - - - - - - - - -	(0·35 to 2·10)	1·04 ap.	(9)
(containing Nitrous Nitrogen) - - - - -	(0·04 to 0·44)	0·21	(9)
Total Nitrogen - - - - - - - - - -	(3·47 to 3·66)	3·54	(3)
"Oxygen absorbed" at 27° C. (80° F.) *at once* - - -	(0·62 to 1·11)	0·80	(9)
" " " " *in 4 hours* - - -	(2·02 to 3·86)	2·90	(9)
Dissolved Oxygen taken up in 24 hours at about 18° C. -	(0·36 ap. to 1·35)	0·78 ap.	(8)
Solids in suspension - - - - - - - - -	(2·80 to 15·70)	7·40	(6)
Solids by centrifuge (vols.) - - - - - - -	(33·4 to 193·0)	96·0	(9)
Ratio of solids in suspension to centrifuge solids - -	(1:9·0 to 1:14·3)	1:13·7	(6)
Incubator Test (Scudder) - - - - - - -	4 +, 5 —		(9)
Incubator Test (by smell) - - - - - - -	6 +, 1 (?), 2 —		(9)
Smell when drawn - - - - - - - -	6 +, 1 (?), 1 —		(8)
Smell when analysed - - - - - - - - -	8 +, 1 (?)		(9)
*Oxygen in solution (c.c. per litre) - - - - - -	0·0 to 3·0	1·6 ap.	(7)

These chance samples of shallow filter effluent were, generally speaking, of the same character and appearance as the various other effluents already described. Six out of eight had a clean smell when drawn, and eight out of nine a clean smell when analysed, while six—or possibly seven—out of nine withstood incubation. The average (approximate) figure for absorption of dissolved oxygen was 0·78, as against 0·54 in the chance samples of deep filter effluent, *i.e.*, about half as much again. The solids in suspension showed great variations (2·8 to 15·7), but they averaged about the same as in the effluents from the deep filter, *i.e.*, 6 to 7 parts; hence filtration or settlement is required here also.

Taken all over, these chance samples of shallow filter effluent are by no means so good as the hourly samples, nor are they so good as the chance samples of deep filter effluent, though the difference is not extreme. It is probably due to the larger volume of precipitation liquor treated on the shallow filter. Still, all the figures of analysis go to indicate that the purification effected by the shallow filter has not gone quite so far as that done by the deep filter (judged by the ordinary chance samples of effluent from both). The shallow filter effluents may be regarded as effluents of fair or moderate quality, which would be much improved by the separation of their matter in suspension.

* Those figures are to be taken as approximate only. Four of the estimations were made by the copper chloride method, and three by the manganese method.

Compared respectively (*a*) with the hourly samples of sewage; (*b*) the hourly samples of precipitation liquor; and (*c*) the nine chance samples of precipitation liquor drawn between November 27th, 1902 and August 19th, 1904, *i.e.*, within practically the same limits of time as the nine chance samples of shallow filter effluent, these chance samples of effluent show the following reduction in figures :—

Calculated on	Sewage.	Precipitation Liquor.	
	Hourly Samples.	Hourly Samples.	Chance Samples.
Ammoniacal Nitrogen - - -	31 per cent. reduction	—	—
Albuminoid Nitrogen - - -	70 „ „	3 per cent. reduction	—
"Oxygen absorbed" *at once* - -	73 „ „	2 „ „	39 per cent. reduction
„ „ *in 4 hours* -	69 „ „	7 „ „	37 „ „
Solids in suspension - - -	79 „ „	+196 „ „	—
Solids by centrifuge (vols.) - -	64 „ „	+405 „ „	+97 „ „

One gets, however, a better comparison of the relative purification effected by the deep and shallow filters, by taking only those corresponding effluents drawn at the same times. In each case there were nine effluents, the numbers being :—

Deep: Nos. 3,081, 3,122B, 3,137A, 3,141A, 3,276, 3,341, 3,415B_2, 3,547, and 3,552.

Shallow: Nos. 3,082, 3,122A, 3,137A_2, 3,141A_2, 3,277, 3,342, 3,414B, 3,546, and 3,553.

The filters may be taken as having on the average treated approximately :—Deep filter, 190 gallons per cube yard; shallow filter, 280 gallons per cube yard per day.

The average figures of analysis were :—

Parts per 100,000.	Deep.	Number of Estimations.	Shallow.	Number of Estimations.
Ammoniacal Nitrogen - - - - - -	2·29	(6)	2·61	(6)
Albuminoid Nitrogen - - - - - -	0·25	(5)	0·31	(5)
Oxidized Nitrogen - - - - - -	1·14	(9)	1·04 ap.	(9)
(*containing Nitrous Nitrogen) - - -	0·11	(9)	0·21	(9)
Total Nitrogen - - - - - - -	4·81	(4)	3·54	(3)
"Oxygen absorbed" *at once* - - - -	0·73	(9)	0·80	(9)
„ „ *in 4 hours* - - - -	2·62	(9)	2·90	(9)
*Dissolved Oxygen taken up in 24 hours at about 18°C.	0·58 ap.	(8)	0·78 ap.	(8)
Solids in suspension - - - - - -	7·38	(7)	7·40	(6)
Solids by centrifuge (vols.) - - - - -	75·0	(9)	96·0	(9)
Ratio of solids in suspension to centrifuge solids -	1 : 11·9	(7)	1 : 13·7	(6)
Incubator Test (Scudder) - - - - -	7+, 2—,	(9)	4+, 5—	(9)
Incubator Test (by smell) - - - - -	9+	(9)	6+, 1 (?), 2—,	(9)
Smell when drawn - - - - - -	6+, 3 (?)	(9)	6+ 1 (?), 2—,	(8)
Smell when analysed - - - - - -	8+, 1 (?)	(9)	8+1 (?)—	(9)
*Oxygen in solution (c.c. per litre) - - -	2·6 ap.	(7)	1·6 ap.	(7)

* Approximate figures.

The foregoing columns of figures, which are as nearly as possible comparative, show that there was not really very much difference in the degree of purification of the deep and shallow filter effluents over a period of nearly two years, when the deep filter was treating on the average 190 gallons and the shallow filter 280 gallons per cube yard per day. The deep filter effluents were, however, the better of the two.

Bacteriological Notes.—Fifteeen samples were examined bacteriologically. The B. coli test and presumptive tests for B. coli usually yielded positive results with from ·0001 c.c. to ·00001 c.c. (10,000 to 100,000 per c.c.); but a fair proportion of the samples yielded negative results with ·0001 c.c. (less than 10,000 per c.c.). As regards the B. enteritidis sporogenes test, three samples contained 10, ten samples contained 100, and two samples contained 1,000 spores of this anaerobe per c.c. It should be noted that sample 3564 and later samples were collected after the rates of flow in connection with the deep and shallow filters had been adjusted in the manner described in the text of this report.

Comparison of the two Effluents.—The effluents from the deep and shallow filters did not differ bacteriologically from each other materially, and it is difficult to state definitely which filter yielded the better results. On the whole, however, the deep filter seemed to yield bacteriologically the better results.

It is interesting to note that a fair proportion of the effluents, both from the deep and shallow filters, yielded relatively good results bacteriologically, despite the large volume of precipitation liquor being treated, and the coarse nature of the filtering material.

Description of the Sample.	Number of B. coli (or gas-forming coli-like Microbes).	B.S. = Bile-Salt Glucose Peptone Test. N.R. = Neutral Red Broth Test. In. = Indol Test. L.P.M. = Lactose Peptone Milk Test.	B. Enteritidis Sporogenes Test.	Remarks.
3082. Horfield shallow filter effluent, 20/12/02.	—	100 not 1,000 B.S. 1,000 not 10,000 N.R. 100 not 1,000 L.P.M.	100 not 1,000	"Gas" test + 1 c.c. (24 hours at 20° C.).
3122A. Horfield shallow filter effluent, 12/3/03.	—	10,000 not 100,000 N.R.	100 not 1,000	
3137A². Horfield shallow filter effluent, 26/4/03.	—	10,000 not 100,000 N.R.	100 not 1,000	
3141A². Horfield shallow filter effluent, 3/5/03.	—	1,000 not 10,000 N.R.	100 not 1,000	
3150. Horfield shallow filter effluent, 12/5/03.	—	1,000 not 10,000 N.R.	100 not 1,000	
3152. Horfield shallow filter effluent, 13/5/03.	—	1,000 not 10,000 N.R.	10 not 100	
3156. Horfield shallow filter effluent, 14/5/03.	—	1,000 not 10,000 N.R.	10 not 100	
3342. Horfield shallow filter effluent, 17/12/03.	10,000 not 100,000 (− indol) (+ clot)	10,000 not 100,000 N.R.	100 not 1,000	
3414B¹. Horfield shallow filter effluent, 3/3/04.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R.	100 not 1,000	

Description of the Sample.	Number of B. coli (or gas-forming coli-like microbes).	B.S.=Bile Salt Glucose Peptone Test. N.R.=Neutral Red Broth Test. In.=Indol Test. L.P.M.=Lactose Peptone Milk Test.	B. enteritidis sporogenes test.	Remarks.
3546. Horfield shallow filter effluent, 19/8/04.	10,000 not 100,000 (– indol) (– clot)	10,000 not 100,000 B.S. 100,000 N.R.	100 not 1,000	
3553. Horfield shallow filter effluent, 7/10/04.	100,000 (+ indol) (+ clot)	100,000 B.S. 100,000 N.R.	100 not 1,000	
3564. Horfield shallow filter effluent, 16/11/04.	100,000 (– indol) (– clot)	100,000 B.S. 10,000 not 100,000 N.R.	100 not 1,000	
3576. Horfield shallow filter effluent, 30/11/04.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 B.S. 10,000 N.R.	10 not 100	
780. Horfield shallow filter effluent, 4/1/05.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 B.S. 10,000 not 100,000 N.R.	1,000 not 10,000	
3624. Horfield shallow filter effluent, 9/3/05.	100,000 (+ indol) (+ clot)	100,000 B.S. 10,000 not 100,000 N.R.	1,000 not 10,000	

Flow of Precipitation Liquor on to the two Filters at Horfield.—Up to November the 9th, 1904, the shallow filter was fed with precipitation liquor through a small circular hole placed in the channel. Alteration in the head of water in the channel caused this flow to vary considerably, but not in proportion to the alterations in the flow on to the deep filter, which was fed direct from the open channel. In consequence, the shallow filter received during the greater portion of the observations more than its true proportion of precipitation liquor in dry weather, and less than its true proportion when the flow of sewage was largely swollen by rain.

The earlier observations, therefore, were made upon the filters as they were found working; but on November 9th, 1904, small weirs of widths proportionate to the cubic contents of each filter were placed in the feed channels, and the observations were then continued with the filters treating approximately equal amounts, per cube yard, of the same precipitation liquor at all states of the flow. These latter observations are placed under the head of an experiment in a later paragraph.

In May, 1903, when the flow of sewage was gauged, measurements were also made of the flow of precipitation liquor to the two filters. At this time, during a dry weather flow of 50,000 gallons per day, 43,000 gallons were found to flow to the deep filter and 7,000 to the shallow filter, or a proportion of, roughly, six to the deep filter and one to the shallow filter at this state of the flow. Taking this proportion as being approximately the true one for dry weather flows, and using the true dry weather flow of 38,000 gallons per day as the basis of calculation, the amount treated per cube yard on the two filters in perfectly dry weather would be approximately 115 gallons per cube yard per 24 hours on the deep filter, and 196 gallons per cube yard per 24 hours on the shallow filter.

On another day during the same period of measurements, out of a total of 65,000 gallons per 24 hours, 57,000 were treated upon the deep filter and 8,000 on the shallow filter.

Using this proportion, therefore, and estimating the average daily flow in all weathers to be equivalent to 62,350 gallons per day, the average amounts treated by the filters during the first portion of our observations would be 190 gallons per cube yard per 24 hours for the deep filter, and 280 gallons per cube yard per 24 hours for the shallow filter.

Effect of Temperature upon the Working of the Stoddart Filters.—The importance of gaining some evidence as to the working of the Stoddart filters, and especially of the Stoddart trays, during severe weather, has been constantly in mind during these observations, and many visits were paid to the Horfield works with this object in view; but no very cold winds or severe frosts occurred at any time, and it is consequently impossible to state what the effect would be of severe weather. In ordinary cold weather and frost, however, the working of the filters was not affected, except in so far that there was a slight lowering in temperature of the effluents, and this was more marked in the case of the shallow filter effluent than of the deep.

The lowest temperatures measured were 5·5°C. (41·9°F.) for the deep filter effluent, and 4°C. (39·2°F.) for the shallow filter effluent. The temperature of the tank liquor going on to the filters was 7°C. (44·6°F.) in each case. This was during a cold day following dry, frosty weather, in March, 1904.

The temperature observations included measurements made every few hours through out a fortnight in April and May, 1903, and isolated measurements on the occasion of each visit to the works.

Experiment for the Comparison of the Deep and Shallow Filters, when each was treating Precipitation Liquor continuously at the same rate per cube yard per day.

For the reasons which have been stated previously it was found necessary, after the first part of the observations, to divide the flow to the filters into proportions equivalent to the cubic contents of each, in order to make a more exact comparison of the work done by the two filters.

On Wednesday, November 9th, 1904, therefore, 2 weirs, of widths proportionate to the cubic contents of each filter, were fitted in the main feed channel, and from this time to the end of the observations in August, 1905, the two filters treated precipitation liquor at approximately the same rate per cube yard per day. In order to make an absolute comparison it would have been necessary to have re-arranged the troughs and feed channels on the shallow filter, so as to make them exactly like those on the deep filter, for, according to Mr. Stoddart, the arrangement adopted for the latter is the correct one. The faulty arrangement of the troughs on the shallow filter undoubtedly affected the distribution, and on many occasions it could by no means be called good; but notwithstanding this, we do not think the results have been seriously affected, and, from notes made of the appearance and character of the effluent, on no occasion was an effluent drawn from the shallow filter, the inferiority of which could be put down to bad distribution.

Experimental Samples from Deep and Shallow Filters.—The following are the principal *average* figures given by the four experimental samples of precipitation liquor, Nos. 3574, 3577, 778 and 3623; the five experimental deep filter effluents, Nos. 3563, 3575, 3578, 779 and 3625; and the five experimental shallow filter effluents, Nos. 3564, 3576, 3579, 780 and 3624. Excepting that no sample of precipitation liquor was drawn to correspond with the effluents Nos. 3563 and 3564, the different sets of samples are strictly comparable. In each case three of the effluents were drawn in dry and two in very wet weather.

Parts per 100,000.	Precipitation Liquor.	Number of Estimations.	Deep Filter Effluent.	Number of Estimations.	Shallow Filter Effluent.	Number of Estimations.
Total Nitrogen	7·16	(4)	—			
Oxidized Nitrogen	—	—	0·94 ap.	(5)	0·86 ap.	(5)
(Including Nitrous Nitrogen)	—	—	0·13	(5)	0·20	(5)
"Oxygen absorbed" at 27°C *at once*	1·44	(4)	1·10	(4)	1·17	(4)
" " at 27°C *in 4 hours*	5·48	(3)	3·52	(5)	3·62	(5)
Dissolved Oxygen taken up in 24 hours at 18°C.	—		1·65	(4)	1·94	(4)
Dissolved Oxygen taken up by filtered or settled liquid	—		0·69	(5)	0·86	(5)
Solids by centrifuge (vols.)	63·4	(4)	93·0	(5)	79·0	(5)
Equal, *roughly*, to Solids in suspension	11·0		7·0 to 8·0		6·0 to 7·0	
Incubator test (Scudder)			2+	(2)	2+	(2)
Incubator test (by smell)			3+, 2—	(5)	3+2—	(5)
Smell when drawn			2+, 1?, 1—	(4)	3+1—	(4)
Smell when analysed			2+, 2?, 1—	(5)	3+, 1?, 1—	(5)

The four samples of precipitation liquor were very uneven in composition, two of them being about twice as strong as the other two. On the other hand the last-drawn samples, though not rich in nitrogen, contained as much as **20** parts of suspended solids (of which **8** were organic), washed down by a storm. It requires but a glance at the figures of analysis of the effluents to see that neither the deep nor the shallow filter experimental effluents were anything like so good as the ordinary chance samples. Indeed, as effluents they were unsatisfactory, even although this was in part due to the large quantities of suspended solids that they contained. It is hardly possible to draw a distinction between them as regards quality, but if there was a difference, then the deep filter effluents were probably a trifle the better.

In order to get an idea of the extent to which the suspended solids in the effluents affected the general figures of analysis, and especially the rate of absorption of dissolved oxygen, seven of the samples of deep filter effluent and six of the shallow filter effluent were examined in duplicate, *i.e.*—

(*a*) The effluent as a whole;

(*b*) The effluent after filtration through paper or settlement for **1** to **2½** hours. In each case the last two out of the seven and six, respectively, were settled, the others being filtered.

The deep filter samples, Nos. **3,415B²**, **3,547**, **3,552**, **3,575**, **3,578**, **779** and **3,625** comprised four of the experimental effluents, and the shallow filter samples, Nos. **3,546**, **3,553**, **3,576**, **3,579**, **780**, and **3,624** also comprised four; hence, the appended figures must not be taken as illustrative of the purity of an ordinary Horfield effluent after paper filtration or settlement—they are merely to be read for purposes of comparison. The following are the *average* figures obtained; the figures in brackets represent the number of estimations in each case. The effect of the separation of the suspended solids is very marked.

Parts per 100,000.	Deep Filter Effluents.		Shallow Filter Effluents.	
	Original.	Filtered or Settled.	Original.	Filtered or Settled.
"Oxygen absorbed" at 27° C. *at once*	1·04 (6)	0·70 (6)	1·16 (5)	0·79 (6)
" " " *in 4 hours*	3·19 (7)	2·19 (7)	3·64 (6)	2·51 (6)
Dissolved Oxygen taken up in 24 hours at 18° C. - - - -	1·12 (7)	0·55 (7)	1·60 (6)	0·71 (6)
Solids in suspension - - -	9·10 (4)	—	9·50 (3)	—
Solids by centrifuge (vols.) - -	65·0 (7)	* 3·5 (7)	76·0 (6)	* 4·1 (7)
Incubator Test (Scudder) - -	4 +, (4)	6 + (6)	1 +, 2 − (3)	4 + 1 (probably) − (5)
Incubator Test (by smell) -	5 + 2 −, (7)	† 5 +, 1 − (6)	4, + 2 −, (6)	5 + 1 (probably) − − (6)

The following comparative figures show the rate at which dissolved oxygen was taken up by a few of these effluents (*a*) in **24** hours and (*b*) in **72** hours:—

	No. 3,415B₂.		No. 3,547.		No. 3546.	
	Original.	Filtered.	Original.	Filtered.	Original.	Filtered.
Dissolved Oxygen taken up in 24 hours at 18° C. - - - - - -	0 25	0·18	0·48	0·11	0·63	0·18
" " " 72 "	2·23	0·83	1·97	0·51	2·13 + x	0·99

As already stated, these three samples were of rather poor quality and not typical of the average Horfield effluent, and it is noteworthy that in every case the absorption of dissolved oxygen was more rapid on the second and third days than on the first, though

* The small centrifuge figures for the two settled samples have in each case been averaged over the whole seven or six. † Probably 6 +.

in the filtered samples it was never great. Our experience with effluents of high class has usually been that any absorption is rather more rapid on the first day than the second, and so on.

It may be of interest to refer in some detail here to the effluents drawn from both deep and shallow filters at times of very heavy flow. Taking groups of samples corresponding to one another, we have :—

Parts per 100,000.	No. 3,137A. Precipitation Liquor.	No. $3,137A_1$. Deep Filter Effluent.	No. $3,137A_2$. Shallow Filter Effluent.
Flow (gallons per cube yard).=		730.	313.
Oxidized Nitrogen - - - - - - -		0·50 ap.	0·45 ap.
" Oxygen absorbed at 27° C. (80° F.) *in* 4 *hours* -	4·16	4·51	2·57
Solids in Suspension - - - - - -	11·32	16·25	7·12
Incubator Test (by smell) - - - - -	—	+ or (?)	+

In this case, with less than half the flow per cube yard, the effluent from the shallow filter was distinctly the better of the two, but that from the deep filter contained an abnormal quantity of suspended solids ; even with this it practically withstood incubation.

Parts per 100,000.	No. 3,139. Precipitation Liquor.	No. 3,139A. Deep Filter Effluent
Flow (gallons per cube yard). =		966.
Oxidised Nitrogen - - - - - - - - - -	0·44 ap	0·77 ap.
" Oxygen absorbed " at 27° C. (80° F.) *in* 4 *hours* - - - -	3·59	2·61
Solids by centrifuge (vols.) - - - - - - -	52·0	64·0
Incubator test (by smell) - - - - - - - - -	—	+

Here a non-putrefactive effluent of fair quality was obtained from the deep filter.

Parts per 100,000.	No. 3,141. Precipitation Liquor.	No. 3,141A. Deep Filter Effluent.	No. $3,141A_2$ Shallow Filter Effluent.
Flow (gallons per cube yard). =		710.	375.
Oxidized Nitrogen - - - - - -	0·21	0·63 ap.	0·99 ap.
" Oxygen absorbed " at 27° C. (80° F.) *in* 4 *hours*	3·78	2·44	2·13
Dissolved oxygen taken up *in* 24 *hours* - -		0·64 ap.	0·36 ap.
Solids in suspension - - - - - -		7·0	6·0
Solids by centrifuge (vols.) - - - - -	37·0	80·0	132·0
Incubator test (by smell) - - - - -	—	+	+

Here the smaller flow on to the shallow filter resulted in a better effluent, but the difference between the two was not very marked.

Parts per 100,000. =	No. 3,276. Deep Filter Effluent.	No. 3,277. Shallow Filter Effluent.
Flow (gallons per cube yard) =	810.	416.
Oxidized Nitrogen - - - - - - - - - - -	1·35	1·55
"Oxygen absorbed " at 27° C. (80° F.) *in* 4 *hours* - - - -	2·07	2·14
Dissolved oxygen taken up *in* 24 *hours* - - - - - - -	0·50 ap.	0·46 ap.
Solids in suspension - - - - - - - - -	4·90	2·80
Incubator test (by smell) - - - - - - - - -	+	+

With the smaller flow per cube yard, the shallow filter effluent was on the whole the better, but again there was not much difference.

Parts per 100,000.	No. 3577. Precipitation Liquor.	No. 3,578. Deep Filter Effluent.	No. 3,579. Shallow Filter Effluent.
Flow (gallons per cube yard)=		617.	584.
Oxidized Nitrogen	—	1·24	1·22
"Oxygen absorbed" at 27°C. (80°F.) *in* 4 *hours*	4·51	2·32	2·57
Dissolved oxygen taken up *in* 24 *hours*:			
(*a*) By original sample		1·20	1·20
(*b*) By filtered sample		0·15	0·45
Solids by centrifuge (vols.)	72·0	55·0	72·0
Incubator test (by smell)		+	+

The deep filter effluent was in this case rather the better, but again there was not much difference.

Parts per 100,000.	No. 3,623. Precipitation Liquor.	No. 3,625. Deep Filter Effluent.	No. 3,624. Shallow Filter Effluent.
Flow (gallons per cube yard)=		1,077.	1,076.
Oxidized Nitrogen		0·70 ap.	0·75 ap.
"Oxygen absorbed" at 27° C. (80° F.) *in* 4 *hours*	4·65	4·27	4·11
Dissolved oxygen taken up *in* 24 *hours* at 18° C.:			
(*a*) By original sample		2·23	2·49
(*b*) By filtered sample		1·04	1·36
Solids in suspension	20·40	18·00	15·60
Solids by centrifuge (vols.)	152·0	135·0	100·0
Incubator test (by smell):		—	—
(*a*) Original sample		+	+
(*b*) Filtered sample		+	+

The deep filter effluent was again rather the better, but there was little difference between the two.

The main conclusions to be drawn from these results are :—

1. That with very heavy flows of dilute precipitation liquor, lasting from 5 to 29 hours (up to 966 gallons per cube yard on the deep filter and up to 584 gallons per cube yard on the shallow filter), non-putrefactive effluents (suspended solids included) were obtained.

2. That with relative flows of roughly 2 volumes per cube yard on to the deep filter and one volume per cube yard on to the shallow filter (the actual flows of dilute precipitation liquor being high), rather better effluents were obtained from the shallow filter, but the difference was not very great.

3. That when the flows per cube yard were approximately the same, the deep filter effluent was rather the better, but again the difference was not very marked.

4. That with flows of fully 1,000 gallons per cube yard, both filters yielded putrefactive effluents, the solids being included, but these were rendered non-putrefactive by the suspended solids being removed.

5. That very large quantities of suspended solids are washed through the filters in times of heavy flow.

SUMMARY.

The sewage is one of about average strength, perhaps under the average; it contains considerable quantities of subsoil water, probably constituting about one-third of its total volume in dry weather. The flow is subject to extreme fluctuations during rainfall, a volume equal to twenty times the dry-weather flow having been actually gauged by us, while the sewer can and does at times take up to twenty-five times this flow (a rate of one million gallons per 24 hours). The whole of this is treated at the works, no storm water being allowed to pass away.

The precipitation effected in dry weather is very satisfactory, the suspended solids in the average hourly samples examined not amounting to more than 2·5 parts. In wet weather these solids are considerably increased, about twice as much having been found in the chance as in the hourly samples. The effective settlement which was generally obtained was, we think, mainly due (1) to the form of the tank, the sewage being delivered into it at a great depth below the surface, while the over flow cill is very long, because of the circular form of the tank (the clarified liquid escapes slowly all round the top); and (2) to the method by which the precipitant is added to the sewage. It is, however, necessary to point out that the tanks do not effect nearly such good settlement in times of storm, the increased rate of flow of sewage down the central shaft evidently disturbing the sludge already accumulated at the bottom of the tank. This is a case in which an empty reserve tank for storm water would be advantageous.

The filters are constructed of carefully selected gas-works clinker, graded as nearly as possible to pieces of 3-inch diameter. A noteworthy point about their construction is that, practically speaking, three out of the four sides are built merely of very large pieces of clinker, with only a slight batter, *i.e.*, those sides have no retaining walls proper. The piers which carry the distributing channels no doubt help to maintain the stability of these clinker "walls," but still the construction is interesting as showing that deep percolating filters can be built without containing walls of masonry, and also without the waste of much filtering material. From the fact that the filters have shown no signs of clogging after 4 years' use, and that they continue to yield good results, it follows that the filtering material is well adapted—both as regards nature and size—to the treatment of the fluctuating volumes of the particular precipitation liquor. The comparatively slight disintegration of this material is the result of its having been very carefully selected in the first instance.

Taking the distribution on to the deep filter as typical of the Stoddart process, each tray on this filter being carried on girders supported by brick piers and being fed at both ends, the distribution at Horfield has been uniformly efficient during our observations, though not perfect. It has, of course, to be borne in mind that comparatively large volumes of a not very strong liquor are ordinarily being dealt with. The trays require very little attention, and only need to be cleaned out once a month. A strong point in their favour is that, when called upon—as they often are—to deal with very large increases in the normal flow of precipitation liquor, the distribution improves instead of deteriorating. In fact, it may be said generally that the trays act better the larger the flow they have to deal with, and they possess the further advantage of requiring only a very small head of liquid. We have never observed any freezing of the liquid in the trays at Horfield during moderate frosts, but have had no experience of a prolonged period of severe weather there. We have not noticed any serious buckling of the trays.

Having given the results of our actual observations, we may perhaps be allowed to add, as an expression of opinion, that the weak points of this method of distribution seem to be:—(1) that with a small flow of a strong sewage any defects of distribution would be magnified, and this would have to be provided for in the construction of the filters; (2) that there might be greater difficulties in getting and in maintaining true levels over a large area, unless the filters were built in small units; and (3) that, with trays of such comparatively thin metal, there must always be some danger of buckling.

The samples of effluent from the deep filter were of very fair quality, though not of the highest class; the last few samples examined were not up to the average standard of the others. Out of twenty tested, the three hourly samples and fifteen of the chance ones, *i.e.*, eighteen in all, withstood incubation; and the majority of them took up only moderate amounts of dissolved oxygen from solution. At the same time many of these effluents contained large quantities of suspended solids, the settlement of which would have been desirable; if this were done, the effluents as a whole would benefit greatly.

The effluents from the shallow filter were as a whole not so good as those from the deep filter; this was, however, no doubt due to the larger volumes of precipitation liquor treated per cube yard on the shallow filter at the times when the sewage was strongest, and also to the less perfect distribution on to that filter. Taking only the more strictly comparable samples of effluent from the two filters, when each was

treating approximately the same volume of liquor per cube yard, there was little to choose between them, but probably the deep filter effluents were a trifle the better; unfortunately the majority of the experimental samples were drawn at times of very heavy flow.

The observations on the two filters have led us to the general conclusion that, where the levels allow of it, a deep filter is on the whole preferable to a shallow one, since faults of distribution are toned down more in the former case. With proper care, however, a shallow filter (3 feet in depth) can quite well be made to give satisfactory results in the treatment of a precipitation liquor like that at Horfield.

The smell arising from the works at Horfield varies very much; sometimes there is little or none, while at other times we have observed it to be very pronounced. The strong smell appears to be due to the nature of the sewage, since it is noticeable at the sewage inlet; it probably arises to some extent from the discharge of the foul liquid of the latrines at the barracks, this liquid coming to the works three times a day. The precipitation tanks being covered in, the smell rises from the tank liquor channel and from the immediate neighbourhood of the distributing trays. The Stoddart method of distribution involves the exposure of a large surface of liquid immediately over the top of the filter, but this apparently tends to concentrate or localise any smell and to largely prevent its wide diffusion by wind. It probably explains the fact that while we have on many occasions been conscious of a strong smell on the works themselves, no smell was evident a short distance away.

The ditch into which the effluents from the filters discharge appeared during our investigations to be polluted with sewage above the works. Observations upon it were therefore useless.

We should like, in conclusion, to express our thanks to Mr. F. Wallis Stoddart, F.I.C., Mr. T. H. Yabbicom, city engineer of Bristol, and Mr. C. Walker, manager of the Horfield sewage works, for the assistance they have given us in connection with our work at Horfield.

KINGSTON-UPON-THAMES SEWAGE WORKS.

(Corporation of Kingston-upon-Thames.)

1. Situation of Works - - - - - -	Within half a mile of the centre of Kingston.
2. Methods of treatment - - - - - -	*General process.*—About 2,750,000 gallons per day. Chemical precipitation with continuous flow subsidence (A.B.C. process). *Experimental process.* — About 12,000 gallons per day. Chemical precipitation, continuous flow subsidence, and single contact.
3. Population draining to works during observations - - - - - - -	53,454 (estimated average).
4. Water supply in gallons per head and whence obtained - - - - - - -	About 25 gallons. From Lambeth district of Metropolitan Water Board—a fairly hard water.
5. Number of W.C.'s - - - - - - -	About 14,000.
6. Sewerage system - - - - - -	Chiefly combined. Surbiton and Hampton Wick partially separate.
7. Average dry weather flow in gallons per 24 hours	2,750,000.
8. Gallons of sewage per head per day - - -	51·4.
9. Character of the sewage - - - - -	Domestic, with some Brewery, Tannery and Gas liquor refuse.
10. Period of observations - - - - -	October, 1902 to October, 1906.
11. Age of experimental contact beds - - -	(1) Coke bed, 4½ years; (2) Clinker bed, 2¼ years.
12. Amount of storm water treated - - -	About twice the dry weather flow.
13. Total capacity of tanks in gallons - - -	1,200,000

14. Total area of experimental contact beds in yards super - - - - - - -	48·8.
15. Total cubic content of experimental contact beds in yards cube - - - - - - -	48·8.
16. Nature of filtering material - - - -	One bed fine coke and one fine clinker.
17. Gallons of precipitation liquor treated on experimental contact beds per yard super and per yard cube per 24 hours - - - -	Coke, 209; clinker, 269.
18. The final effluent is discharged into - - -	The river Thames, rather below Kingston railway bridge.

FLOW OF SEWAGE.

As a result of the access of surface water to the sewers during wet weather, the flow of sewage becomes much swollen at such times. Not more than about twice the dry weather flow, however, is treated at the works, the rest being diverted into the river by overflows placed on the main sewers. There are in all five such overflows; two on the Kingston main sewer, two on the Surbiton main sewer, and one on the Hampton Wick main sewer.

Occasionally, owing to the older Kingston sewers being laid in low-lying ground, the river rises in flood to such an extent as to pass back over some of these overflows into the sewers, the system thus becoming waterlogged. This has only occurred, however, five times within the last ten years.

As continuous records of the total flow of sewage are kept by the Native Guano Company, we have thought it unnecessary to make any such gaugings for the Commission, but, having checked the readings of the recorder over a period of seven days, we have made our calculations from the figures supplied to us by the Company.

The average dry weather flow is approximately 2,250,000 gallons per day. The highest day's flow of 2,500,000 gallons per 24 hours occurs on the Tuesday and Wednesday of the week, and the lowest day's flow of 2,000,000 gallons per 24 hours on the Sunday.

The average daily flow treated throughout the years of observation (1903, 1904 and 1905) may be taken to have been approximately 2,750,000 gallons. The maximum rate of flow to the works in wet weather is about 4,000,000 gallons per 24 hours.

As the whole of the sewage is pumped, the variations in flow are artificial. It may be said, however, that, in general, about 80 per cent. of the sewage comes down during the sixteen day hours, as against about 20 per cent. during the eight night hours, and that apart from the two large variations caused by the cutting out at night of one of the pumps, or bringing one in in the early morning, the flow is of a steady character.

Subsoil Water.—A considerable quantity of subsoil water gains access to the sewers.

Screens.—The whole of the sewage flowing to the Kingston works is screened before it passes to the precipitation tanks, the screens consisting of grids, three-quarters of an inch apart. These screens are raked by hand about once an hour, the matter removed being heaped upon the works and ultimately taken away by farmers free of charge. Approximately, eight barrow loads of screenings are removed per day.

Screened Sewage.—Three sets of hourly samples and four chance samples were examined chemically. The hourly sets, Nos. 589, 591 and 595, were drawn over the usual three days (Monday to Thursday) in the latter half of July, 1903, in dry weather, excepting that 0·03″ of rain fell during the second day. They gave the following figures on analysis. Alongside are given the figures for the chance sample No. 594, which was

drawn on July 23rd, 1903, at 3.30 a.m., and which was supposed to represent the weakest sewage of the 24 hours :—

Hourly Samples. Parts per 100,000.		Average.	Number of Estimations.	Chance sample No. 594.
Ammoniacal Nitrogen	(3·70 to 4·03)	3·85	(3)	3·07
Albuminoid Nitrogen	(0·81 to 0·95)	0·86	(3)	0·96
Total Organic Nitrogen	(1·16 to 1·91)	1·63	(3)	—
Total Nitrogen	(4·86 to 5·86)	5·49	(3)	—
"Oxygen absorbed" at 27°C. (80°F). *at once*	(2·92 to 3·65)	3·25	(3)	4·00
" " " " *in 4 hours*	(9·44 to 11·52)	10·66	(3)	10·45
Chlorine	(8·96 to 9·68)	9·43	(3)	—
Solids in suspension	(23·0 to 44·8)	31·00	(3)	69·0
Solids by Centrifuge (vols.)	(126·0 to 167·0)	142·0	(3)	Too coarse.
Ratio of Solids in suspension to Centrifuge solids	(1 : 3·7 to 1 : 5·5)	1 : 4·8	(3)	—

The first and third of these hourly samples contained gas liquor, the smell of which was apparent on the morning of analysis, while the second contained tan refuse. In one of the samples rather large fragments of fat were present. The three sets were very uniform in composition, excepting that the first (drawn Monday and Tuesday) contained almost twice as much suspended solids as the others, this being no doubt due to the fact that Monday is washing day at Kingston. Taken all over, the Kingston dry-weather sewage may be looked upon as being of about average strength in oxidizable matter, as measured by the 4-hours "oxygen absorbed" test; but perhaps a little below average as regards nitrogenous matter.

The sample of night sewage was as strong as the average of the hourly samples and contained fully twice as much suspended solids (*i.e.*, 69 parts), these being of a very coarse character and including pieces of green weed. The unusual strength of this sample is probably accounted for by the length of time taken by the Hampton Wick sewage to reach Kingston by the Shone ejector system.

Of the other three chance samples of sewage examined partially, No. 3027, was an afternoon sample, drawn in October, 1902, in practically dry weather; No. 474, a sample taken about mid-day in February, 1903, also in dry weather; and No. 3171, an afternoon sample drawn in June, 1903, in excessively wet weather, with the Thames in flood and the river water flowing into the sewer through the storm overflow. The analytical figures for these may be given separately :—

Parts per 100,000.	No. 3027.	No. 474.	No. 3171.
Ammoniacal Nitrogen	—	6·13	—
Albuminoid Nitrogen	—	1·30	—
Total Organic Nitrogen	—	3·58	—
Total Nitrogen	—	9·71	—
"Oxygen absorbed" at 27°C. (80°F.) *at once*	3·89	5·27	1·24
" " " " *in 4 hours*	15·15	14·68	5·24
Chlorine	—	8·26	—
Solids in suspension	—	36·6	8·0
Solids by Centrifuge	286·0	Too coarse.	49·0
Ratio of solids in suspension to Centrifuge solids	—	—	1 : 6·1

The above figures show that the afternoon sewage at Kingston is in dry weather very strong, and that its suspended solids are at times very coarse. The sewage is liable to great dilution in times of heavy rain.

Bacteriological Notes.—Ten samples of Kingston crude sewage were examined bacteriologically. Nine out of the ten samples yielded positive results with the B. Coli test and presumptive tests for B. Coli, with 1/100,000 c.c.

As regards the B. Enteritidis sporogenes test, one sample contained 10,000, three samples 1,000, and six samples 100 spores of this anaerobe per c.c.

Description of the Sample.	Number of B. Coli (or Gas-forming Coli-like Microbes).	B.S.=Bile Salt Glucose Peptone Test. N.R.=Neutral Red Broth Test. In=Indol Test. L.P.M=Lactose Peptone Milk Test.	B. Enteritidis Sporogenes Test.	Remarks.
3,027. Kingston Crude Sewage. 14/11/02.	100,000 (+indol) (+clot)	100,000 B.S. 100,000 N.R. 100,000 In 100,000 L.P.M.	At least 10,000	"Gas" Test, +·001 c.c.;—·0001 c.c. Gelatine (24 hours at 20°C.).
474. Kingston Crude Sewage. 2/2/03.	100,000 (+indol) (+clot)	100,000 B.S. 100,000 N.R. 100,000 In. 100,000 L.P.M.	1,000 not 10,000	"Gas" Test, + ·01 c c.;—·001 c.c. Gelatine (24 hours at 20° C.).
3,171. Kingston Crude Sewage. 21/6/03.	—	100,000 N.R.	1,000 not 10,000	
588. Kingston Crude Sewage. 21/7/03.	—	100,000 N.R.	100 not 1,000	
591. Kingston Crude Sewage. 22/7/03.	—	100,000 N.R.	100 not 1,000	
594. Kingston Crude Sewage. 23/7/03. (Weak).	—	10,000 not 100,000 N.R.	100 not 1,000	
595. Kingston Crude Sewage. 23/7/03.	—	100,000 N.R.	100 not 1,000	
(A) Kingston Crude Sewage. 8/8/04.	100,000 (+indol) (+clot)	100,000 B.S. 100,000 N.R. 100,000 L.P.M.	100 not 1,000	
(C) Kingston Crude Sewage. 11/8/04.	100,000 (+indol) (+clot)	100,000 B.S. 100,000 N.R. 100,000 In. 100,000 L.P.M.	100 not 1,000	
(E) Kingston Crude Sewage. 12/8/04.	100,000 (+indol) (+clot)	100,000 B.S. 100,000 N.R. 100,000 In. 100,000 L.P.M.	1,000 not 10,000	

PRECIPITATION TANKS.

Number - - - -	8.
Size of each - - - -	85 feet by 50 feet.
Average of working depth - -	6 feet.
Capacity of each - - -	150,000 gallons.
Total capacity - - - -	1,200,000 gallons.

Construction.—The precipitation tanks are constructed of brick and cement, with concrete bottoms. They are divided longitudinally by a brick and cement wall extending about three-quarters of the entire length, and are fitted with floating arms for the purpose of withdrawing the supernatant liquor, previous to sludging.

The sewage enters each tank through a wide penstock, and, having passed down one division and under two scum-boards, flows back through the other division, and so—by means of another penstock—to the entrance of the second tank. The draw-off in the last tank is made by means of a bell-mouthed pipe, which is protected by a floating scum-board in the form of a box without top or bottom.

Precipitants.—The precipitants used are alumino-ferric, blood, charcoal and clay, together equal to about fifty grains per gallon of sewage in dry weather. The blood, charcoal and clay are ground up with a little sewage in a mortar-mill, and the mixture is run into a small tank, where it is further diluted, preparatory to being mixed with the sewage. The alumino-ferric is added subsequently, in the form of a solution.

Flow-Through.—With the average number of tanks (five) in use, and the average daily flow of 2,750,000 gallons, the flow through is once in 6·5 hours, at the rate of about 11·4 inches per minute.

Working.—The sewage, as it flows along the inlet channel, is divided into roughly equal portions, half flowing through the precipitation tanks on the one side and half through those on the other.

In dry weather, two tanks on each side are sufficient to produce effective settlement, but in wet weather three tanks on each side are often required.

The average number of tanks in use is five, and these are used in two series of two or three tanks. The first tank in a series is cleaned out every six or seven days, and the second or third tank in a series about once a fortnight.

Sludging.—When it becomes necessary to sludge one of the tanks, the supernatant liquor is first drawn off as far as possible by means of a floating arm, the thicker part of the liquor close to the sludge at the bottom being subsequently pumped back into the tanks which are being used for the treatment of the incoming sewage. The liquid sludge is then pumped by means of a small Tangye ram pump into a large sludge well, whence it is sucked into an air-tight chamber, and from there forced into the presses by means of compressed air.

There are sixteen presses provided for this latter purpose, each working on an average about 1·38 times per day. As each press produces about 16 cwt. of pressed cake, the total quantity of pressed cake made is about 17·6 tons per day, or about 6,000 to 6,500 tons per year.

The pressed cake is next broken up as well as possible in a small mill and passed by means of a hopper through the drying plant, where it is raised to a temperature of about 75°C., and from which it emerges in the form of a moist powder. This, after storing under cover, becomes the "Native Guano" which is placed upon the market. As a rule, it is stored for six months before being sent out.

The proportion of water in the tank sludge is probably about 90 per cent., in the pressed cake about 50 per cent., and in the Native Guano about 25 per cent.

Native Guano.—A sample of native guano (A), made up of eighty-five different fractions, was drawn on March 23rd, 1905, and examined both chemically and bacteriologically. It was in a fine state of division. In the second column are given the figures of analysis of another sample of native guano (B), examined partly in October, 1904, and partly in January, 1905. The following results were obtained :—

——	A.	B.
Moisture (at about 110°C.)	25·87 per cent.	10·19 per cent.
Matter volatile on ignition	37·99 „	45·08 „
Non-volatile matter	36·14 „	44·73 „
	100·0 per cent.	100·0 „
Grit (*i.e.*, matter insoluble in hydrochloric acid, after ignition)	22·33 per cent.	28·04 „
*Oxide of iron and alumina	10·10 „	11·59 „
†Lime	3·30 „	4·78 „
Magnesia	—	0·42 „
Potash (soluble in dilute hydrochloric acid)	0·16 approx.	—
Potash (soluble in water)	0·06 „	—
Phosphoric acid (P_2O_5)	1·74 „	2·35 „
Equivalent to tribasic phosphate of lime	3·80 „	5·13 „
Nitrogen (total)	1·93 „	2·49 „
Nitrogen evolved as ammonia on boiling for 2 hours with a dilute solution of potash (0·5 per cent. KOH)	0·41 „	0·50 „
Do. do. *in* 6 *hours*	—	0·60 „

* This figure will include the phosphoric acid and probably also some lime.
† May contain a small quantity of magnesia.

Allowing for the difference in moisture, the above two samples have almost the same composition, but B is slightly richer in nitrogen and phosphoric acid than A.

Bacteriological Analysis.— SAMPLE A.

Kingston Native Guano.

Average of 85 samples. 23rd March, 1905.

B. Coli Test.—Negative result with 1 gramme.

Neutral Red Broth Test.—As regards fluorescence, + $\frac{1}{1000}$; − $\frac{1}{10000}$ of a gramme. Growth in tube inoculated with one-10,000-millionth of a gramme, indicating the survival of an enormous number of bacteria.

B. Enteritidis Sporogenes Test.— + $\frac{1}{1000}$ − $\frac{1}{10000}$ of a gramme.

Precipitation Liquor.—Three sets of hourly samples and twenty chance samples were examined chemically, the latter including seven which were drawn to correspond with the experimental samples of effluent referred to later. The hourly samples, Nos. 589, 592 and 596, were drawn in July, 1903, in practically dry weather, at the same time as the hourly samples of sewage. They gave the following results on analysis:—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(3·57 to 3·76)	3·64	(3)
Albuminoid Nitrogen	(0·38 to 0·49)	0·44	(3)
Total Organic Nitrogen	(0·56 to 1·00)	0·82	(3)
Total Nitrogen	(4·26 to 4·76)	4·47	(3)
"Oxygen absorbed" at 27°C. (80°F.) *at once*	(1·50 to 1·73)	1·62	(3)
" " " " *in 4 hours*	(4·89 to 5·57)	5·17	(3)
Chlorine	(8·80 to 9·36)	9·06	(3)
Solids in Suspension	(1·52 to 2·06)	1·46	(3)
Solids by Centrifuge (vols.)	(12·0 to 13·0)	12·0	(3)
Ratio of Solids in Suspension to Centrifuge Solids	(1 : 6·3 to 1 : 7·8)	1 : 7·0	(3)

It requires but a glance at the above figures of analysis to see that these hourly sets of precipitation liquor were uniform in composition. In appearance they were opalescent, with very small quantities of whitish flocculent sediment, and they all had a faint sewage smell on the morning of analysis (the last one had a smell of gas liquor when drawn, and this had not entirely disappeared by the following morning). The striking point about this precipitation liquor is its freedom from suspended solids, the average over the three days being only 1·46 parts. In other respects it was not strong organically, the 4 hours "oxygen absorbed" average figure being 5·17 and that for organic nitrogen 0·82. The result of the precipitation process at Kingston, therefore, is to produce an exceptionally well clarified liquor of only moderate organic strength.

Compared with the hourly sets of sewage samples, these hourly sets of precipitation liquor show the following reduction in figures:—

Calculated on:—	Reduction.
Total Nitrogen	19 per cent.
Ammoniacal Nitrogen	5 " "
Albuminoid Nitrogen	49 " "
Total Organic Nitrogen	50 " "
"Oxygen absorbed" *at once*	50 " "
" " *in 4 hours*	58 " "
Solids in Suspension	95 " "
Solids by Centrifuge (vols.)	92 " "

Chance Samples.—The nineteen ordinary chance samples of precipitation liquor examined were Nos. 3028, 475, 505, 525, 527, 3172, 618, 3272, 646, 664, 699, 3569, 775, 3649, 3652, 3662, 3665, "C." and 2. Three-fourths of these were drawn in the cooler months of the year (October–March) and the remainder in May, June and August, while nearly half

were taken in dry weather and the remainder in wet. The hours of drawing varied between 10.20 a.m. and 7.40 p.m., but thirteen of the samples were taken between 12.10 noon and 2.40 p.m. Speaking generally, therefore, these chance samples of precipitation liquor may be taken as representing a fair average of what is treated on the filters; perhaps, on the whole, they represent a slightly more dilute liquor than the average for the whole year.

The following results were obtained :—

Parts per 100,000		Average.	Number of Estimations.
Ammoniacal Nitrogen	(2·39 ap. to 4·94)	3·38	(10)
Albuminoid Nitrogen	(0·31 to 0·74)	0·44	(8)
Total Organic Nitrogen	(1·23 to 1·98)	1·48	(7)
{ Oxidized Nitrogen	(0·0 to 1·18 ap.)	0·37	(16)
{ Containing Nitrous Nitrogen	(0·0 to 0·22)	0·04	(16)
Total Nitrogen	(2·66 to 6·66)	4·60	(10)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(0·46 to 1·67)	0·98	(18)
,, ,, ,, ,, *in 4 hours*	(2·18 to 6·51)	4·39	(19)
Dissolved oxygen taken up in 24 hours at about 18° C.	(0·39 ap. to 6·47)	*2·85 ap.	(13)
Chlorine	(4·62 to 8·00)	6·75	(8)
Solids in suspension	(1·50 to 3·06)	2·40	(6)
Solids by centrifuge (vols)	(trace to 52·0)†	11·0	(18)
Ratio of solids in suspension to centrifuge solids	(1 : 0·7 to 1 : 17·0)	1 : 5·5	(6)

In appearance these chance samples were usually opalescent or slightly turbid, sometimes almost colourless, but generally of a slight brownish tint. The smell, as a rule, was not strong; sometimes the liquor had a sewage and sometimes a soapy smell, while in a few cases it smelt of tar or resin, etc. The maximum figure found for suspended solids was 3·06 parts, and in most cases (as judged by centrifuge figures) there was less than 1 part present. The separation of the suspended matter of the sewage by this precipitation process has thus been consistently good throughout the whole time of our observations. An unusually large number of the samples were found to contain very appreciable quantities of nitrate on the day of analysis, indicating, in the first instance, the presence of subsoil water in the original sewage, and, in the second, the comparatively stable character of this liquor, so far as the reduction of nitrate within one day of sampling is concerned. At the same time this cannot be ascribed to a deficiency in the number of microbes present, although it has to be borne in mind that the liquor is somewhat dilute organically. We are unable to say whether the nature and the large quantity of precipitants used have any temporarily restraining effect on the vitality of the bacteria. As bearing on this point it may be mentioned that—for a precipitation liquor—it took up comparatively little dissolved oxygen from water in 24 hours. No sample, however, out of eight tested, was able to withstand incubation. These chance samples of precipitation liquor showed of course much greater variations in composition than the hourly ones, but the average figures are in both cases much the same.

Compared with hourly samples of sewage, the chance samples of precipitation liquor show the following reduction in figures :—

Calculated on :—	Reduction.	Number of Estimations.
Total Nitrogen	16 per cent.	(10)
Ammoniacal Nitrogen	12 ,,	(10)
‡Albuminoid Nitrogen	49 ,,	(8)
Total Organic Nitrogen	9 ,,	(7)
"Oxygen absorbed" *at once*	70 ,,	(18)
,, ,, *in 4 hours*	59 ,,	(19)
Solids in suspension	92 ,,	(6)
Soilds by centrifuge (vols)	92 ,,	(18)

* This figure is too low, as in some cases all the oxygen was exhausted, and the first few estimations were only approximate. The average for the last seven samples was 4·22.

† This figure was quite exceptional. There were only three samples out of eighteen which showed a centrifuge figure of above 14·0.

‡ The reduction figures for albuminoid and total organic nitrogen are based, for the most part, on the stronger chance samples.

The following figures are given in detail, in order to show more particularly the absorption of dissolved oxygen by the Kingston precipitation liquor:—

Number of Sample.	3569	775	3652	3662	3665	C	2
Total Nitrogen - - - -	5·89	3·24	5·63	6·66	4·51	4·97	4·69
Solids in Suspension - - - -	2·60	—	—	1·90	—	—	2·55
Solids by Centrifuge (Vols.) -	1·8	7·0	5·3	4·0	5·6	8·4	4·8
"Oxygen absorbed" *in* 4 *hours* at 27°C - - - -	4·68	3·02	5·70	6·51	3·38	4·43	5·08
Dissolved oxygen taken up from water at 18°C. in 1 to 56 days*	Days=28 / † 25·6 ap.	1 / 2·21, 14 / 21·5, 28 / 26·7	1 / 6·47	1 / 6·2, 56 / 78·0	1 / 3·19	1 / 4·20, 56 / 36·6	1 / 3·02

The above figures are interesting as showing that in this well clarified precipitation liquor the amount of dissolved oxygen taken up from tap water in 24 hours at 18°C. (at moderate dilutions, ranging from 4 to 14) is in most cases fairly comparable with the amount taken up from acid permanganate in 4 hours at 27°C.; and, further, that the maximum quantity taken up from water in 56 days (at a dilution of 99) was 78 parts approximately.

The subject is discussed in connection with the results of similar estimations upon a number of other samples. ‡

Bacteriological Notes.—Twenty-two samples of precipitation liquor were examined bacteriologically.

Nearly all the samples yielded positive results with the B. Coli test, and presumptive tests for B. Coli, with 1/10,000 to 1/100,000th c.c.

As regards the B. Enteritidis sporogenes test, six samples contained 100, thirteen samples 10, and three samples less than ten spores of this anaerobe per c.c.

Description of the Sample.	Number of B. Coli (or Gas-forming Coli-like Microbes).	B.S.=Bile Salt Glucose Peptone Test. N.R.=Neutral Red Broth Test. In.=Indol Test. L.P.M.=Lactose Peptone Milk Test.	B. Enteritidis Sporogenes Test.	Remarks.
3028. Kingston Precipitated tank liquor. 14/10/02.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 B.S. 10,000 not 100,000 N.R. 10,000 not 100,000 In. 100,000 L.P.M.	10 not 100	"Gas" Test, + ·01 cc. – ·001 cc. Gelatine (24 hrs. at 20°C.)
475. Kingston precipitated tank liquor. 2/2/03.	10,000 not 100,000 (+ indol) (+ clot)	1,000 not 10,000 B.S 10,000 not 100,000 N.R. 10,000 not 100,000 In. 10,000 not 100,000 L.P.M.	Less than 10	"Gas" Test Negative ·1 cc. Gelatine (24 hrs. at 20°C.) Number of Bacteria (Gelatine at 20°C.) 150,000 per cc.
525. Kingston precipitated tank liquor. 4/5/03.	—	100,000 N.R.	10 not 100	
527. Kingston precipitated tank liquor. 7/5/03.	—	10,000 not 100,000 N.R.	100 not 1,000	
3172. Kingston precipitated tank liquor 21/6/03.	—	100,000 N.R.	10 not 100	

* The above estimations were done in unjointed bottles, and no correction was made for the gas evolved during the period of aeration.

† This figure is not quite exact. By an oversight the capacity of the bottle in which the estimation was made was not measured, and it had to be inferred.

‡ *cf.* Memorandum on "Strength" of Sewage, Appendix IV to Fifth Report (separate volume).

Description of the Sample.	Number of B. Coli (or Gas-forming Coli-like Microbes).	B.S.=Bile Salt Glucose Peptone Test. N.R.=Neutral Red Broth Test. In.=Indol Test. L.P.M.=Lactose Peptone Milk Test.	B. Enteritidis Sporogenes Test.	Remarks.
589. Kingston precipitated tank liquor. 21/7/03.	—	100,000 N.R.	10 not 100	
592. Kingston precipitated tank liquor. 22/7/03.	—	100,000 N.R.	Less than 10	
596. Kingston precipitated tank liquor. 23/7/03.	—	100,000 N.R.	100 not 1,000	
618. Kingston precipitated tank liquor. 7/10/03.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R.	100 not 1,000	
619. Kingston precipitated tank liquor. 7/10/03.	100,000 (+ indol) (+ clot)	100,000 N.R.	10 not 100	
646. Kingston precipitated tank liquor. 10/12/03.	1,000 not 10,000 (+ indol) (+ clot)	1,000 not 10,000 N.R.	10 not 100	
664. Kingston precipitated tank liquor. 2/2/04.	100,000 (+ indol) (+ clot)	100,000 N.R.	10 not 100	
699. Kingston precipitated tank liquor. 31/5/04.	100,000 (+ indol) (+ clot)	100,000 B.S. 100,000 N.R.	10 not 100	
(B). Kingston precipitated tank liquor. 8/8/04.	100,000 (– indol) (+ clot)	100,000 B.S. 100,000 N.R. 100,000 L.P.M.	100 not 1,000	
(D). Kingston precipitated tank liquor. 11/8/04.	100,000 (– indol) (+ clot)	100,0000 B.S. 100,000 N.R. 10,000 not 100,000 In. 100,000 L.P.M.	100 not 1,000	
(F). Kingston precipitated tank liquor. 12/8/04.	100,000 (– indol) (+ clot)	100,000 B.S. 100,000 N.R. 100,000 In. 100,000 L.P.M.	10 not 100	
3569. Kingston precipitated tank liquor. 28/11/04.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 B.S. 100,000 N.R.	10 not 100	
775. Kingston precipitated tank liquor. 3/1/05.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 B.S. 1,000 not 10,000 N.R.	10 not 100	
3649. Kingston precipitated tank liquor. 17/8/05.	—	10,000 not 100,000 B.S. 100,000 N.R.	10 not 100	
3662. Kingston precipitated tank liquor. 17/10/05.	—	100,000 B.S. 10,000 not 100,000 N.R.	100 not 1,000	
3665. Kingston precipitated tank liquor. 13/11/05.	—	10,000 not 10,000 B.S. 10,000 not 100,000 N.R.	10 not 100	
(C). Kingston precipitated tank liquor. 31/1/6.	—	10,000 not 100,000 B.S. 1,000 not 10,000 N.R.	1 not 10	

THE EXPERIMENTAL SINGLE CONTACT BED PROCESS

(Native Guano Company's Beds).

Number of beds - - - -	2.
Size of each - - - -	20 feet by 11 feet.
Area of each - - - -	24·4 square yards.
Total area - - - -	48·8 „ „
Depth of material - - -	3 feet.
Cubic content of each - -	24·4 cube yards.
Total cubic content - - -	48·8 „ „
Material - - - - -	No. 1 Bed.—Coke graded as follows:—(Top) 2 feet 3 inches, $\frac{1}{4}$ inch to 1 inch in diameter; (Bottom) 9 inches of coarse coke. No. 2 Bed.—Furnace clinker graded as follows:—(Top) 2 feet, 3 inches, $\frac{1}{4}$ inch to $\frac{3}{8}$ inch in diameter; (Bottom) 9 inches of coarse clinker.

Construction.—The filter tanks are constructed of cement concrete throughout.

Distribution.—The distribution is effected by means of shallow wooden troughs, carried diagonally from each corner of the bed and crossing at the centre. The troughs rest on the surface of the material.

Underdraining.—One main drain, constructed of three-inch agricultural pipes, down the centre of the bed, fed by three lines of three-inch agricultural pipes (unjointed), laid herring-bone fashion on either side.

Age of the Beds.—The coke bed was first brought into use on May 24th, 1898. The clinker bed was started on June 24th, 1902.

Working.—As these small contact beds were constructed by the Native Guano Company for experimental purposes, their working has varied considerably, as follows :—

Coke Bed.		Clinker Bed.	
Period.	Rate.	Period.	Rate.
May, 1898 – September, 1900 - - - -	3 fillings in 12 hours -		
September, 1900 – January, 1901 - - - -	4 fillings in 12 hours -		
January, 1901 – October, 1901 - - - -	6 fillings in 18 hours -		
October, 1901 – July, 1902.	4 fillings in 12 hours -	June, 1902 – July, 1902 -	4 fillings in 12 hours -
July, 1902 – September, 1904 - - - -	3 fillings in 12 hours -	July, 1902 – September, 1904 - - - -	3 fillings in 12 hours -
September, 1904 – November, 1904 - - -	4 fillings in 12 hours -	September, 1904 – November, 1904 - - -	4 fillings in 12 hours
November, 1904–February, 1906 - - - -	6 fillings in 24 hours -	November, 1904 – February, 1906 - - -	6 fillings in 24 hours -

The period of contact, however, has been two hours throughout in both cases.

The beds are filled and emptied by hand. They are very occasionally raked and dug over to a depth of about one foot.

Capacity.—Coke Bed.—The original empty tank capacity of the coke bed, according to the dimensions of the tank, was 4,125 gallons, and, assuming that the material when first put in occupied one half of the space of the tank, the original water capacity would be 2,062·5 gallons (*).

The working of the coke bed may be divided into three periods :—

(1) From May 28th, 1898, to March, 1901, when the top 18 inches of material were removed and riddled.

(2) From March, 1901, to November, 1904; and

(3) From November, 1904, to February, 1906, a period during which the number of fillings given to the bed was raised to six per day of 24 hours, at the request of the Commission.

The capacity measurements from November 10th, 1904, to February, 1906, were made for the Commission under our supervision. Those given for dates previous to November, 1904, were made for the Native Guano Company.

(*First Period.*)—The working of the coke bed during the first period was as follows :—

Period.	Rate.
May, 1898, to September, 1900 - - - -	3 fillings in 12 hours.
September, 1900, to January, 1901 - - -	4 fillings in 12 hours.
January, 1901, to March, 1901 - - - -	6 fillings in 18 hours.

The capacity measurements were :—

November, 1899 - 1,225 gallons or 29·6 per cent. of the original empty tank capacity.

December, 1900 - †1,265 gallons, or 30·6 per cent. of the original empty tank capacity.

In the early part of 1901 the bed began to take the precipitation liquor at each filling rather slowly, owing to the breaking down of the surface coke, and in March, 1901, the the top 18 inches of the coke were removed, riddled, and replaced, the loss resulting from the rejection of the small material being made up by the addition of fresh coke.

(*Second Period.*)—During the second period the working of the bed was as follows :—

Period.	Rate.
March, 1901, to October, 1901 - - - -	6 fillings in 18 hours.
October, 1901, to July, 1902 - - - -	4 fillings in 12 hours.
July, 1902, to September, 1904 - - - -	3 fillings in 12 hours.
September, 1904, to November, 1904 - - -	4 fillings in 12 hours.

The capacity measurements were as follows :—

March, 1901 -	1,420 galls. or	34·4	per cent. of the	original empty tank	capacity.
October, 1901 -	1,324 ,,	32	,,	,,	,,
October, 1903 -	1,128 ,,	27·3	,,	,,	,,
November, 1904	1,190 ,,	28·8	,,	,,	,,

* A capacity measurement, which can, however, only be considered approximate, was made by the Native Guano Company three weeks after the coke bed was started, and gave, as a result, the figure of 1,400 gallons for the capacity of this bed. As it is very improbable that as much as 600 gallons of water capacity were lost during the three weeks of working, the assumed figure of 2,062·5 gallons for the original water capacity is probably too high, and in the figures for percentage reduction of capacity we have therefore calculated only from the original empty tank capacity.

† The apparent increase shown by this measurement was thought to be due to a leak.

During the first period of its life the bed received an average of 3·29 fillings per day for nearly three years, the capacity being reduced to 30·6 per cent. of its original empty tank capacity.

During the second period of its life the bed received an average of 3·72 fillings per day for nearly $3\frac{3}{4}$ years, the reduction in this case being to 28·8 per cent. of its original empty tank capacity.

(*Third Period.*)—From November 29th, 1904, till February 21st, 1906—the third period of its life—the bed received, at the request of the Commission, six fillings per day of 24 hours, working continuously at this rate, with the exception of a month's rest in November, 1905.

The capacity measurements relating to this period gave the following results :—

November 10th, 1904	-	1,190 gallons, or 28·8 per cent. of the original empty tank capacity.
November 29th, 1905	-	917 gallons or 22·2 per cent. of the original empty tank capacity.
December 15th, 1905 (after 15 days' rest)	-	1,040 gallons or 25·2 per cent. of the original empty tank capacity.
February 21st, 1906	-	817 gallons or 19·8 per cent. of the original empty tank capacity.

During the whole period of its life the coke bed received an average of 3·93 fillings of precipitation liquor per day for about $7\frac{3}{4}$ years, and its capacity at the end of this time—with one partial renewal of the material—was 19·8 per cent. of the original empty tank capacity.

On March 8th, 1906, the fillings given to the coke bed were increased—again at the request of the Commission—to eight per day of 24 hours.

Clinker Bed.—(Owing to a small leak, the figures of capacity given for the clinker bed cannot be considered quite accurate. An allowance has been made for this by measuring the quantity of liquid leaking away in a given time, and the measurements are thought to give a very fair index of the comparative capacities ; but they are put forward as being only approximate.)

The original empty tank capacity of the clinker bed was 4,125 gallons, and the original water capacity by actual measurement (Native Guano Company) was 1,900 gallons, or 46 per cent. of the original empty tank capacity. After working for eighteen months at an average rate of 3·2 fillings per day (three months at 4 fillings in 12 hours, and fifteen months at 3 fillings in 12 hours), the capacity of the clinker bed on November 10th, 1904, was found to be approximately 1,690 gallons. At this time, therefore, it retained 88 per cent. of the original water capacity, or 40·9 per cent. of the original empty tank capacity.

From November 29th, 1904, to February 21st, 1906, the number of fillings given to the clinker bed was raised at the request of the Commission to six per 24 hours. At the commencement of this period of working (December 1st, 1905), the capacity of the bed was found to be approximately 1,355 gallons ; while at the end of the period (February 21st, 1906) it was approximately 1,346 gallons.

After working for three years and ten months, therefore, at an average rate of 4 fillings per day, the capacity of the clinker bed had been reduced to 32·6 per cent. of its original empty tank capacity, or 70·8 per cent. of its original water capacity.

On March 8th, 1906, the number of fillings given to the clinker bed was cut down to four per day of 24 hours.

Filter Effluents.—Coke Bed Effluents.—In addition to special experimental samples, three sets of hourly samples and seven ordinary chance samples of filter effluent from the small coke bed were examined. During the period of time covered by these samples (March, 1903, to November, 1904), the bed was treating precipitation liquor at the rate of three fillings in a day of 12 hours.

The hourly sets, Nos. (590, 599), 593 and 597, were drawn at the same time as the other hourly samples in July, 1903, in practically dry weather. Nos. 593 and 597 each represented four discharges, while Nos. 590 and 599, which are averaged as one sample for

nitrate and "oxygen absorbed" from permanganate, represented two discharges each. The remaining figures taken are those of No. 590, as No. 599 was only partially analysed; this cannot, however, make any appreciable difference in the general average result.

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(1·88 to 2·00)	1·96	(3)
Albuminoid Nitrogen *	(0·18 and 0·20)		(2)
Total Organic Nitrogen	-	?	
Oxidized Nitrogen	(1·11 ap. to 1·32)	1·22	(3)
Containing Nitrous Nitrogen	(0·01 to 0·01)	0·01	(3)
Total Nitrogen	(3·13 to 3·52)	3·33	(3)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(0·16 to 0·32)	0·24	(3)
" " " " *in 4 hours*	(0·67 to 1·04)	0·84	(3)
Incubator Test (Scudder)	-	3 +	(3)
" " (by smell)	-	3 +	(3)
Smell when drawn	-	3 +	(3)
Smell when analysed	-	3 +	(3)
Chlorine	(7·66 to 8·30)	7·93	(3)
Solids in Suspension	(0·94 and 1·32)		(2)
Solids by Centrifuge (vols.)	(19·0 and 8·5)		(2)

These hourly samples of effluent were very uniform in composition. In appearance they were nearly clear or slightly opalescent, and they contained only very small quantities of flocculent suspended matter (about 1 part per 100,000). They had a clean smell when drawn and when analysed, and they all withstood incubation, without much reduction of their nitrate (which constituted about one-third of the total combined nitrogen). The 4 hours' "Oxygen absorbed" figure was low.

Compared with the hourly samples of sewage and of precipitation liquor, they show the following reduction in figures:—

Calculated on—	Compared with— Sewage.	Compared with— Precipitation Liquor.
Total Nitrogen	39 per cent. reduction.	25 per cent. reduction.
Ammoniacal Nitrogen	49 " "	46 " "
Albuminoid Nitrogen	78 " "	57 " "
"Oxygen absorbed" *at once*	93 " "	85 " "
" " *in 4 hours*	92 " "	84 " "
Solids in Suspension	over 90 " "	About the same in both.

Judging from the respective chlorine figures, the hourly samples of filter effluent did not correspond exactly with the hourly samples of sewage and of precipitation liquor, but represented a slightly weaker liquid. Nevertheless, the purification effected in the small coke filter was very good, as measured by the 4 hours "oxygen absorbed" test. The fact of nearly two-thirds of the nitrogen present in the effluents being still in the form of ammonia shows that nitrification was not carried to a great extent here; but, on the other hand, there were only traces of nitrite both before and after incubation, a proof of the stability of the effluents. These effluents may thus be described as of fair to good quality from a chemical point of view (*cf.* chance samples).

Chance Samples.—The seven ordinary chance samples of coke bed effluent examined, Nos. 506, 528, 588A, 617, 3,271, 700, and 3,570, were drawn between March, 1903, and November, 1904, for the most part in the cooler months of the year, and in varying

* The figures for albuminoid nitrogen may possibly be rather too high.

weather as regards rainfall, but mostly in wet or after wet weather. They were all taken between 11.25 a.m. and 3.0 p.m. and all at midflow. They gave the following figures :—

	Parts per 100,000	Average.	Number of Estimations.
Ammoniacal Nitrogen	(0·30 to 2·81)	1·45	(6)
Albuminoid Nitrogen	(0·08 to 0·15)	0·12	(5)
Total Organic Nitrogen	(0·29 ap. and 0·24)	—	(2)
Oxidized Nitrogen	(1·11 to 2·50 ap.)	1·53	(7)
Containing Nitrous Nitrogen	(0·0 or trace)	0·0	(7)
Total Nitrogen	(2·90 to 4·34)	3·43	(3)
Oxygen absorbed at 27° C. (80° F.) *at once*	(0·18 to 0·40)	0·31	(6)
Oxygen absorbed „ „ in *4 hours*	(0·44 to 1·54)	0·96	(6)
Dissolved Oxygen taken up from water in 24 hours at 18°C.	(0·0 to 0·58 ap.)	0·18 ap.	(6)
Incubator test (Scudder)		3 + 1—	(4)
Incubator test (by smell)		7+	(7)
Smell when drawn		6 + 1 slightly—	(7)
Smell when analysed		7+	(7)
Chlorine	(4·10 to 7·46)	6·43	(4)
Solids by centrifuge (vols.)	(trace to under 25·0)	12·0 ap.	(7)
c.c. per litre		—	—
Oxygen in solution when analysed	(0·0 to 2·2 ap.)	1·0	(7)

As was to be expected, these chance samples showed greater differences in composition than the hourly sets. In appearance they were bright and clear, or slightly opalescent, and either colourless or with a very slight brownish tint. Like the hourly samples they contained very little suspended matter, so little, in fact, that it was only estimated approximately by the centrifuge; it would average something like 1 part per 100,000. While the average figures of analysis are not very different from the figures given by the hourly samples, the chance samples were relatively more nitrated, containing nearly half of their nitrogen in the oxidized form. With one exception at the time of drawing, they all had a clean smell, both when drawn and when analysed, and all withstood incubation, while, out of six samples tested for absorption of dissolved oxygen, only one (No. 3570) took up any appreciable amount in 24 hours ; this last effluent came from a precipitation liquor containing some gas refuse. There can, therefore, be no doubt as to the consistently good quality of the effluents from the small coke bed at Kingston, when worked at the rate of 4 fillings of precipitation liquor per day of 12 hours.

Compared with the chance samples of precipitation liquor (a very approximate comparison), they show the following reduction in figures :—

Calculated on :—	Reduction.	Number of Estimations.	
		Precipitation Liquor.	Effluent.
Ammoniacal Nitrogen	57 per cent.	(10)	(6)
Albuminoid Nitrogen	63 „	(8)	(5)
"Oxygen absorbed" *at once*	68 „	(18)	(6)
"Oxygen absorbed" in *4 hours*	78 „	(19)	(6)
Dissolved Oxygen taken up from water in 24 hours	Over 90 „	(13)	(6)
Solids in suspension	About 50 „ probably.	—	—

Clinker Bed Effluents (Chance Samples).—Only one ordinary chance sample of effluent from the small A.B.C. clinker bed was drawn up to December, 1904, *i.e.*, up to the time when the ordinary chance samples of coke bed effluent were concluded. This sample, however, No. 3571, was strictly comparable with the coke bed effluent, No. 3570, drawn at the same time, on Monday, Nov. 28th, 1904, during a cold thaw, after several cold days with frost at night. The following are the respective figures of analysis :—

Parts per 100,000.	No. 3570 A.B.C. Coke Bed Effluent.	No. 3571 A.B.C. Bed Filter Effluent.
Ammoniacal Nitrogen	2·81	3·56
Albuminoid Nitrogen	0·15	0·36
Total Organic Nitrogen	?	1·16
Nitric Nitrogen (including traces of Nitrous Nitrogen)	1·45	0·19
Total Nitrogen	4·34	4·88
"Oxygen absorbed" at 27° C. (80° F.) *at once*	0·38	0·96
" " " " *in 4 hours*	1·54	2·29
Dissolved Oxygen taken up from water in 24 hours at about 18° C.*	0·57 ap.†	1·29
Incubator Test (Scudder)	+	
" " (by smell)	+	—
Smell when drawn	+	+
Smell when analysed	+	?
Chlorine	7·20	6·90
Solids by Centrifuge (vols.)	Trace	2·5
c.c. per litre :		
Oxygen in Solution, when analysed	1·1	1·1

Both of these samples were practically free from matter in suspension, but while the coke bed effluent was of fair quality, that from the clinker contained hardly any nitrate and failed to withstand incubation. We understand that the regular analyses made for the Native Guano Company by Mr. Lloyd have shown the coke bed effluent to be consistently better than that from the clinker.

EXPERIMENT A.

Experimental Samples of Coke and Clinker Effluents.—After having obtained sufficient data with regard to the ordinary working of the coke bed, at the usual rate of 3 fillings of precipitation liquor per day, the Authorities met the wish of the Commission to increase the number of fillings on both coke and clinker beds to 6 per day; this increased rate began, on November 29th, 1904, and it was continued until February 21st, 1906. During this period of 15 months, fourteen strictly comparative samples of effluent were drawn from the two beds, *i.e.*, seven from each, all at mid-flow. Ten of them were drawn in dry, and four in wet weather,—all excepting two in the cooler months of the year. Four were taken about 12.30 noon, and the remainder between 4 and 5 p.m.

The following are the *average* results obtained from these samples, the figures in brackets indicating the number of estimations in each case :—

* For a part of the time the temperature of the incubator fell as low as 12° C.

† 1·17 parts taken up in 48 hours.

Parts per 100,00).	Coke Bed Effluent.	Clinker Bed Effluent.
Ammoniacal Nitrogen - - - - - - -	(1·48 to 4·01) 2·43 (7)	(2·4) to 3·71) 3·10 (7)
Albuminoid Nitrogen - - - - - - -	(0·08 to 0.31 (?)) ‡0·21 (6)	(0·14 to 0·32) ‡0·22 (6)
Total Organic Nitrogen - - - - - -	(0·22 and 0·27) 0·25 (2)	(0·27 to 0·46) 0·37 (4)
∫ Oxidized Nitrogen - - - - - -	(0·0 to 1·03) 0·43 (7)	(0·0 to 0·34) 0·14 (7)
⎩ Containing Nitrous Nitrogen - - - -	(0·0 to 0·01) Trace (7)	(0·0 to 0·03) 0·01 (7)
Total Nitrogen- - - - - - - - -	(2·70 to 3·13) 2·89 (4)	(3·10 to 4·19) 3·74 (4)
"Oxygen absorbed" at 27° C. (80° F.) *at once* - -	(0·15 to 0·81) 0·37 (7)	(0·20 to 1·11) 0·55 (7)
" " " " " *in 4 hours* -	(0·95 to 2·74) 1·39 (7)	(1·19 to 2·70) 1·84 (7)
Dissolved Oxygen taken up from water in 24 hours at about 18°C - - - - - - - -	(0·06 to 2·04) *0·56 (7)	(0.29 to 2·17 + x) †0·92 ap (7)
Incubator Test (Scudder)- - - - - -	4+1 – (5)	2+ (2)
Incubator Test (by smell)- - - - - -	5+2 – (7)	1+6 – (7)
Smell when drawn - - - - - - - -	7+ (7)	7+ (7)
Smell when analysed - - - - - - -	7+ (7)	6+1 (?) (7)
Chlorine - - - - - - - - - - -	(6·32 to 7·80) 6·72 (6)	(5·45 to 7·05) 6·24 (4)
Solids by Centrifuge (vols.) - - - - - -	(3·6 to 20·0) 9·7 (6)	(2·5 to 38·0) 14·6 (6)

Nearly all the above effluents had the usual good appearance of the ordinary ones from Kingston, and they were on the whole very free from matter in suspension. Those from the coke bed had a clean smell, both when drawn and when analysed, and, excepting in one case at the time of analysis, the same may be said with regard to the clinker effluents. On comparing, however, the above two sets of average figures with those of the hourly and ordinary chance samples of coke bed effluent, it will be seen that in both cases nitration had fallen off very much—indeed, there was scarcely any nitrate in the clinker bed effluents. Five out of seven of the coke bed effluents, however, were able to withstand incubation, but only one out of seven of the clinker. With regard to absorption of dissolved oxygen, one of the coke effluents gave a very high figure, two of them gave a figure which was somewhat high, and four gave a low figure; while four of the clinker effluents had a high figure and three a low one.

Taking the results all over, it was evident that the purifying capacity of the clinker bed was overtaxed with six fillings of precipitation liquor per day (373 gallons per cube yard per day), but the results given by the coke bed with six fillings (246 gallons per cube pard per day), while not consistently good, were sufficiently encouraging to allow of a further experimental increase to eight fillings, the clinker bed being put back to four fillings.

It is worthy of note that the two last samples in each case during the experiment with six fillings a day, which were drawn in November and January, show a distinct improvement on the preceding one, drawn in October; this may not improbably have been due to the fact that in winter the liquor treated on sewage filters, generally, is less concentrated than during the warmer months of the year.

Although the figures obtained in the above experiment are not to be taken as typical of the working at Kingston, it may be of interest to contrast them with those from corresponding samples of precipitation liquor, drawn at the same times as the effluents. The comparison is not strictly correct, as there was no sample of precipitation liquor drawn to correspond with the second pair of the effluent samples, and a later sample of

* Excluding one sample, with the very high figure of 2·04, the average for the other six samples was only 0·31.

† Excluding one sample, which took up more than 2·17 parts, the average for the other six was 0·72.

‡ These figures may possibly be a little too high.

liquor, drawn in March, **1906**, has been added; practically speaking, however, it may be taken as right:—

Calculated on :—	Coke Bed Effluents.	Clinker Bed Effluents.
* Total Nitrogen - - - - - - -	40 per cent. reduction.	34 per cent. reduction.
Ammoniacal Nitrogen - - - - -	39 „ „	10 „ „
Albuminoid Nitrogen- - - - - -	49 „ „	46 „ „
"Oxygen absorbed" *at once* - - - -	60 „ „	41 „ „
„ „ *in 4 hours* - - - -	71 „ „	61 „ „
Dissolved Oxygen taken up from water *in 24 hours*	87 „ „	78 „ „
„ „ „ excluding one effluent sample in each case - - -	93 „ „	83 „ „

EXPERIMENT B.

Experimental Samples of Coke and Clinker Effluents, with the Coke Bed receiving 8 fillings, and the Clinker Bed 4 fillings of precipitation liquor per day.—This further change in the rates of treatment on the two beds was made on March 8th, **1906**. Between that date and October 29th, **1906**, six samples of precipitation liquor, six of coke bed effluent, and five of clinker bed effluent were examined, the samples being taken in July, September and October.

The samples of precipitation liquor gave the following results on analysis:—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - - - -	(1·75 to 2·95)	2·62	(5)
Albuminoid Nitrogen - - - - - -	(0·27 to 0·41)	0·33	(5)
Total Organic Nitrogen - - - - - -	(0·55 to 1·27)	0·81	(5)
{Oxidized Nitrogen - - - - - - -	(0·00 to 0·60)	0·30	(5)
{Containing Nitrous Nitrogen - - - -	(0·00 to 0·08)	0·03	(5)
Total Nitrogen - - - - - - -	(2·39 to 4·69)	3·51	(6)
"Oxygen absorbed" at 27° C. (80° F.) *at once* -	(0·44 to 1·48)	0·74	(6)
„ „ „ „ „ *in 4 hours* -	(2·34 to 5·08)	3·63	(6)
Chlorine - - - - - - - - - -	(4·44 to 6·00)	5·43	(3)
Solids in suspension - - - - - - -	(1·0 to 2·6)	1·80	(6)
Solids by centrifuge (vols.) - - - - - -	(Trace to 20·0)	8·20	(6)
Ratio of solids in suspension to centrifuge solids -	1 : 1·8 to 1 : 10·0	1 : 5·3	(5)

In appearance these samples of precipitation liquor were similar to previous ones.

* Only four estimations of total Nitrogen were made in the effluents. The other figures are all based on six or seven estimations.

The corresponding coke and clinker bed effluents gave the following figures:—

Parts per 100,000.	Coke Bed Effluent. Average.	Coke Bed Effluent. No. of Estimations.	Clinker Bed Effluents. Average.	Clinker Bed Effluents. No. of Estimations.
Ammoniacal Nitrogen	(0·59 to 3·66) 2·14	(6)	(1·09 to 2·97) 1·99	(5)
Albuminoid Nitrogen	(0·10 to 0·16) 0·12	(6)	(0·09 to 0·17) 0·14	(5)
Total Organic Nitrogen	(0·20 to 0·37) 0·26	(5)	(0·22 to 0·65) 0·36	(5)
Oxidized Nitrogen	(0·00 to 0·75) 0·26	(6)	(0·00 to 0·50) 0·21	(5)
Containing Nitrous Nitrogen	(0·00 to 0·01) 0·00	(6)	(0·00 to 0·03) 0·01	(5)
Total Nitrogen	(1·57 to 3·47) 2·55	(6)	(1·81 to 3·44) 2·58	(5)
"Oxygen absorbed" at 27° C. *at once*	(0·19 to 0·38) 0·30	(6)	(0·16 to 0·61) 0·35	(5)
" " " *in 4 hours*	(0·55 to 1·20) 0·90	(6)	(0·71 to 1·75) 1·28	(5)
Dissolved Oxygen taken up from water *in 24 hours* at about 18° C.	(0·13 to 0·43) 0·24	(4)	(0·31 to 0·64) 0·48	(2)
Dissolved Oxygen taken up from water *in 5 days* at about 18° C.	(0·42 to 1·31) 0·87	(2)	(0·80 to 1·76) 1·34	(3)
Incubator Test (Scudder)	5 +	(5)	2 + 2 −	(4)
Incubator Test (by smell)	5 + 1 (?)	(6)	3 + 2 −	(5)
Smell when drawn	6 +	(6)	4 + 1 (?)	(5)
Smell when analysed	6 +	(6)	4 + 1 (?)	(5)
Chlorine	(4·84 to 6·75) 6·07	(5)	(4·30 to 6·91) 5·87	(5)
Solids by Centrifuge (vols.)	(3·6 to 157·6) 57·6	(6)	(8·4 to 30·4) 16·2	(5)

All the above effluents were brownish in tint and slightly opalescent, and nearly all of them had a distinct fishy odour, the odour of the clinker effluents being generally the stronger. The solids in suspension were only estimated in two sets of samples, the highest figure obtained being 3·0 per 100,000; these solids were light brown in colour and usually very flocculent.

It will be seen from the figures of analysis that neither of the effluents contained any oxidized nitrogen, to speak of. Still, the coke effluents all withstood the incubator test, but two out of the five clinker effluents failed. Here again, therefore, the coke bed effluents were rather the better.

The 8 fillings per day on the coke bed were equivalent to 260 gallons of precipitation liquor per cube yard per day, while the 4 fillings on the clinker bed were equivalent to 214 gallons per cube yard per day.

It should be added that during this experiment the capacity of the coke bed was reduced from 955 gallons on March 7th to 630 gallons on October 9th, 1906, this 630 gallons being equivalent to 15 per cent. of the original empty tank capacity, or 30 per cent. of the *assumed* original water capacity. The capacity of the clinker bed remained practically constant with the 4 fillings per day. On March 7th, 1906, it was 1,308 gallons, and on October 9th it was 1,300 gallons. This 1,300 gallons is equivalent to 31·5 per cent. of the original empty tank capacity, or 68 per cent. of the *measured* original water capacity.

The general results of experiment B may be summed up shortly as follows :—

	Coke Bed.	Clinker Bed.
Rate of filtration per cube yard for 24 hours - -	260 gallons.	214 gallons.
Reduction in bed capacity during the experiment - -	From 955 to 630 gallons.	No reduction (capacity practically constant at 1,300 gallons).
Quality of effluent - - - - - - - -	The effluent from the coke bed was rather the better.	

Contrasting this experiment (B) with the preceding one (A), the coke bed was treating :—

Experiment A, at 6 fillings per day - - 246 gallons per cube yard per day.
Experiment B, at 8 fillings per day - - 260 gallons per cube yard per day.

The actual volumes treated per cube yard in the two experiments by the coke bed were thus much the same, the increased number of fillings in the last experiment being nearly counterbalanced by loss of capacity.

The clinker bed was treating :—

Experiment A, at 6 fillings per day - - 373 gallons per cube yard per day.
Experiment B, at 4 fillings per day - - 214 gallons per cube yard per day.

In the last experiment, therefore, the clinker bed treated a much smaller volume of liquor per cube yard.

Amount of Precipitation Liquor treated on the Experimental Contact Beds.
(Native Guano Company's Beds.)

Coke Bed.—The average number of fillings given to the coke bed from May 24th, 1898, to February 21st, 1906 was 3·93 per day. Estimating the average capacity of the bed during that time to have been approximately 1,300 gallons, we obtain the following figures for the quantity of precipitation liquor treated:

Per square yard per 24 hours - - - 209 gallons.
Per cube yard ,, - - - 209 ,,

During the second part of our observations the coke bed was worked at a rate of six fillings per 24 hours, and its average capacity has been estimated at approximately 1,000 gallons. For this period, therefore, the rates of filtration were :—

Per square yard per 24 hours - - - 246 gallons.
Per cube yard ,, - - - 246 ,,

Clinker Bed.—The average number of fillings given to the clinker bed from June 24th 1902, when it was first started, to February 21st, 1906, was 4·1 per day. Estimating the average capacity of the bed during this time to have been approximately 1,600 gallons, we obtain the following figures for the quantity of precipitation liquor treated :—

Per square yard per 24 hours - - - 269 gallons.
Per cube yard ,, - - - 269 ,,

During the second part of our observations, the bed received six fillings per 24 hours, and had an approximate average capacity of 1,500 gallons. The rates of filtration for this period, therefore, were:—

Per square yard per 24 hours - - -	373 gallons.
Per cube yard ,, - - -	373 ,,

THE KINGSTON-UPON-THAMES CORPORATION EXPERIMENTAL CONTACT BEDS.

On July 21st, 1902, six experimental contact beds (each 50 feet by 33 feet by 3 feet deep), three consisting of coke and three of clinker, were brought into use by the Kingston-upon-Thames Corporation as a duplicate experiment, for the purpose of ascertaining the effect of single contact filtration of the Native Guano Company's precipitation liquor. It will be noted that these beds were very much larger than the others whose working has just been considered.

After working the beds at the rate of 3 fillings per day for a period of a fortnight, a six months' trial at 6 fillings a day was commenced. It began on September 8th, 1902, and finished on March 8th, 1903, the gaugings being made by Mr. Henry Macaulay, the Borough Surveyor, and the analyses by Dr. H. Beale Collins, the Medical Officer of Health. The results of this experiment seem to have been satisfactory, and the authorities have since extended the method by constructing an installation of six large contact beds (each 100 feet by 100 feet by 3 feet 9 inches in depth) filled with medium sized pan breeze, for the purpose of treating the whole of the precipitation liquor resulting from the Native Guano Company's first process. The installation is now (March, 1906) almost ready to begin work.

The effluents from the coke beds are stated to have been, as a rule, slightly better than those from the clinker beds.

Only three chance samples of effluent, Nos. 476, 3270, and 647, were drawn from these contact beds, and all of them from the coke beds. One was drawn in February, 1903, during the six months' trial, and the other two in October and December, 1903, when the number of fillings given to the beds had been cut down to 4 per day.

They gave the following figures on analysis:—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - - -	(0·51 to 2·84)	1·29	(3)
Albuminoid Nitrogen - - - - - -	(0·08 to 0·17?)	0·12	(3)
Oxidised Nitrogen - - - - - -	(0·47 to 1·46)	1·04	(3)
Containing Nitrous Nitrogen - - - -	(0·0 to 0·02)	0·01	(3)
Total Nitrogen - - - - - - -	(3·59 and 1·87)		(2)
"Oxygen absorbed" at 27° C. (80° F.) *at once* -	(0·16 to 0·22)	0·18	(3)
,, ,, ,, ,, *in 4 hours* -	(0·74 to 1·09)	0·92	(3)
Dissolved Oxygen taken up from water in 24 hours at about 18° C. - - - - - -	(0·03 to 0·28 ap.)	0·16 ap.	(3)
Incubator test (Scudder) - - - - - - - -		2 + 1 slightly —	(3)
,, ,, (by smell) - - - - - - - - -		3 +	(3)
Smell when drawn - - - - - - - - -		3 +	(3)
Smell when analysed - - - - - - - - -		1 (?) 2 +	(3)
Chlorine - - - - - - - -	(3·48 to 7·60)	5·09	(3)
Solids by centrifuge (vols.) - - - - - -	(7·0 to 19·0)	14·4	(3)
c.c. per litre. Oxygen in solution when analysed - - - - -	(0·0 to 2·0)	1·2	(3)

The above effluents were opalescent and almost colourless, and, excepting for some small worms, they contained hardly any sediment. They all had a clean smell when drawn, and—with the possible exception of No. 476—when analysed; all of them withstood incubation and took up but little dissolved oxygen from water. They were, in fact, of the same good character as the effluents from the small coke filter of the Native Guano Company, already described. It is, however, to be noted that No. 476, which was evidently derived from rather strong precipitation liquor, and which was drawn in very cold weather, was by no means equal in quality to the other two samples. These latter were much more dilute and were relatively very well nitrated, indeed, their figures of analysis, generally, were very good.

THE CANDY SHALLOW PERCOLATING FILTER.

A third experiment upon the purification of the Native Guano Company's precipitation liquor was begun on July 21st, 1902. It consisted of a Candy circular filter, 50 feet in diameter and 3 feet deep, constructed of small to medium clinker mixed with polarite, and fed by a Candy revolving sprinkler. The under-draining consisted of open brickwork drains covered with half round pipes, and laid 4 feet apart over the concrete floor of the bed. The filter was below the level of the ground, and was surrounded by a close-built brick wall.

We only began observations at Kingston when this experiment was nearing its end, and were only able to draw two samples; but we understand that so long as the surface of the filter was kept free, the effluent remained uniformly non-putrescible, notwithstanding the large quantity of precipitation liquor treated (at the commencement of the experiment this was something like 700 to 900 gallons per cube yard per day). Three or four weeks after the filter was brought into use, however, a thick short-fibre growth made its appearance on the surface of the material and flourished to such an extent that eventually the filter became ponded; and, although the filter continued in use until July, 1903, the actual experiment by Mr. Candy was discontinued at the end of September, 1902, chiefly owing to the fact that the level of the outlet channel did not allow of a free outflow for the effluent; under those circumstances it was impossible to secure free drainage and ventilation for the filter. In the main, therefore, this experiment cannot be said to have been carried out under proper conditions, and the results are, in consequence, inconclusive.

It is to be regretted that the experiment was abandoned, for if some means of preventing the growth on the surface could have been found,* and if the outlet channel could have been lowered so as to allow of the free drainage of the filter, the probability is that the method would have compared favourably with the contact plan of filtration. It would also have afforded an opportunity of making some observations upon the important question of growths. Although this has often attracted attention, it still requires careful investigation to ascertain the conditions favourable to growths, and the methods by which they can be prevented.

In regard to the growth, an exactly similar phenomenon has been observed on a very small percolating filter (also 3 feet deep, but consisting of coarse coke), which was constructed by the Native Guano Company and brought into use on March 10th, 1904. The same growth (apparently) made its appearance during the winter of that year, and, after completely covering the surface of the material so as to produce ponding, began to break up during the warmer weather of March, 1905. In this case the working of the filter was continued, with the result that the growth eventually broke up altogether, and only re-appeared during the winter of 1905. At the present time (March, 1906), the growth is again rapidly breaking up and being carried away in the effluent.

Percolating Filter Effluents.—Only three samples of percolating filter effluent from Kingston were examined, viz., : Nos. 477 and 526, from the Corporation Candy Filter, and No. 725, from the small experimental percolating filter of the Native Guano Company. No. 526 was noted as having a slight sewage smell when drawn, but they all had a clean smell when analysed, and all withstood incubation and took up only moderate quantities of dissolved oxygen from water. They were thus of fair quality. It would, however, be

* *Cf.* Commission Experiments at Coleburn (6th Report) and at Dorking (5th Report, Appendix IV).

unwise to attempt to draw any deductions from only one or two samples, The actual figures obtained were :—

———	Corporation Candy Filter.		Native Guano Company's Filter.
	No. 477* Drawn, Monday, Feb. 2nd, 1903, 1 p.m., in cold dry weather.	No. 526 Drawn, Monday, May 4th, 1903, 7.55 p.m., after rain.	No. 725 Drawn, Monday, July 25th 1904, 2.45 p.m., in wet weather.
Ammoniacal Nitrogen	2·72		1·73
Albuminoid Nitrogen	0·17		0·29
Total Organic Nitrogen	0·42		
Oxidised Nitrogen	0·56	0·57	1·86 ap.
Containing Nitrous Nitrogen	0·04	0·02	0·26
Total Nitrogen	3·70		
"Oxygen absorbed" at 27° C. (80° F.) *at once*	0·48	0·34	0·48
" " " " *in 4 hours*	1·70	0·99	1·60
Dissolved Oxygen taken up in 24 hours at about 18°C.	0·36 ap.	0·17	0·40
Incubator Test (Scudder)	+		+
Incubator Test (by smell)	+	+	+
Smell when drawn		slightly −	
Smell when analysed	+	+	+
Chlorine	7·30		7·62
Solids in Suspension			2·50
Solids by Centrifuge (vols.)	5·2	6·0	49·6
c.c. per litre.			
Oxygen in Solution	2·3 ap.	1·75	

Absorption of Dissolved Oxygen by the Effluents from the Corporation Contact and Percolating Filters and the Candy Percolating Filter.—The following figures showing the rate of absorption of dissolved oxygen by various of the foregoing effluents are of some interest :—

	No. 588A Coke Bed Effluent.
Solids by Centrifuge (Vols.)	12·0
Incubator Test (by smell)	+
"Oxygen absorbed" at 27° C. *at once*	0·28
" " " *in 4 hours*	1·11

	in 24 hours at 18°C.	in 6 hours at 27°C.	in 4 hours at 37°C.
Dissolved Oxygen taken up from water	0·12	0·03	0·0

The actual absorption here was very small.

———	No. 725. Effluent from Native Guano Co's. Percolating Filter.	
	Original.	Filtered through paper.
Solids in Suspension	2·5	—
Solids by Centrifuge (Vols.)	49·0	—
Incubator Test (by Smell)	+	—
"Oxygen absorbed" at 27° C. *at once*	0·48	—
" " " *in 4 hours*	1·60	—
Dissolved Oxygen taken up from water in 24 hours at 18°C.	0·40	0·12

* Drawn on the tenth day of working after the reconstruction of the filter.

The suspended solids of this effluent were thus responsible for two-thirds of the whole quantity of dissolved oxygen taken up.

No.	700	3653	3654	3663	3666	3667	B	A
Effluent from Contact Bed	Coke.	Coke.	Clinker.	Coke.	Coke.	Clinker.	Coke.	Clinker.
Solids by Centrifuge (Vols.)	23·0	5·0	9·7	12·2	9·0	38·0	8·4	9·0
Incubator Test (by smell)	+	+	−	+	+	+	+	−
"Oxygen absorbed" at 27° C. *at once*	0·40	0·30	0·59	0·29	0·15	0·35	0·25	0·38
"Oxygen absorbed" at 27° C. *in* 4 *hours*	1·04	1·05	2·15	1·42	0·96	1·32	0·99	1·45
Dissolved oxygen taken up from water in one to five days at about 18°C.	Days * 1 2 4 ·22 ·44 ·88	Days 1 4 ·06 ·74	Days. 1 4 1·01 2·30	Days. 1 2 ·58 ·76	Days. 1 5 ·13 ·44	Days. 1 5 ·29 1·08	Days. 1 5 ·21 ·86	Days. 1 5 ·43 1·48

All the above effluents, excepting No. **700**, were experimental effluents, drawn when the beds were each treating **6** fillings of precipitation liquor per day. On looking at their figures of analysis, it will be seen that, in nearly every case, absorption of dissolved oxygen by the effluent went on somewhat more rapidly during the first day than during the succeeding ones (counting, as the first day, the one following the day of sampling). It will be noted that Effluent "A," though it did not give at all an excessive figure for dissolved oxygen absorption, failed to withstand incubation, (it only contained, however, **0·13** part of nitric nitrogen).

Bacteriological Notes (*all filter effluents*).—Fifteen samples of coke bed and seven samples of clinker bed effluent were examined bacteriologically. The results varied considerably, and no striking or uniform distinction between the coke and clinker effluents could be established. Taking all the results together, about one half the samples yielded negative results with the B. coli test and presumptive tests for B. coli with $\frac{1}{10000}$ c.c. As regards the B. enteritidis sporogenes test, no less than **14** out of **22** samples yielded negative results with $\frac{1}{10}$ c.c., and **4** of the **14** samples contained no spores of this anærobe even in **1** c.c. The effluents were thus usually satisfactory and above the average for contact bed processes of sewage treatment.

A few samples of Corporation coke bed and Candy filter effluent were also examined bacteriologically. The results likewise were good.

Description of the Samples.	Number of B. Coli (or Gas-forming Coli-like Microbes).	B.S. = Bile Salt Glucose Peptone Test. N.R. = Neutral Red Broth Test. In. = Indol Test. L.P.M. = Lactose Peptone Milk Test.	B. Enteritidis Sporogenes Test.	Remarks.
528. Kingston A.B.C. coke effluent. **7/5/03**.	—	100 not 1,000 N.R.	1 not 10	
590. Kingston A.B.C. coke effluent. **21/7/03**.	—	10,000 not 100,000 N.R.	10 not 100	
593. Kingston A.B.C. coke effluent. **22/7/03**.	—	10,000 not 100,000 N.R.	Less than 1	
597. Kingston A.B.C. coke effluent. **23/7/03**.	—	100,000 N.R.	1 not 10	
599. Kingston A.B.C. coke effluent. **23/7/03**.	—	100,000 N.R.	10 not 100	
617. Kingston A.B.C. coke effluent. **7/10/03**.	100,000 (− indol) (− clot)	100,000 N.R.	10 not 100	
3271. Kingston A.B.C. coke effluent. **26/10/03**.	1,000 not 10,000 (+ indol) (+ clot)	1,000 not 10,000 N.R.	1 not 10	

* Each day as nearly as possible **24** hours.

Description of the Samples.	Number of B. Coli (or Gas-forming Coli-like Microbes).	B.S. = Bile Salt Glucose Peptone Test. N.R. = Neutral Red Broth Test. In. = Indol Test. L.P.M. = Lactose Peptone Milk Test.	B. Enteritidis Sporogenes Test.	Remarks.
700. Kingston A.B.C. coke effluent. 31/5/04.	10,000 not 100,000 (– indol) (+ clot)	10,000 not 100,000 B.S. 10,000 not 100,000 N.R.	1 not 10	
3570. Kingston A.B.C. coke effluent. 28/11/04.	1,000 not 10,000 (+ indol) (+ clot)	10,000 not 100,000 B.S. 10,000 not 100,000 N.R.	10 not 100	
776. Kingston A.B.C. coke effluent. 3/1/05.	100 not 1,000 (+ indol) (+ clot)	100 not 1,000 B.S. 1,000 not 10,000 N.R.	10 not 100	
781. Kingston A.B.C. coke effluent. 1/2/05.	1,000 not 10,000 (+ indol) (+ clot)	1,000 not 10,000 B.S. 1,000 not 10,000 N.R.	1 not 10	
3650. Kingston A.B.C. coke effluent. 17/8/05.	—	10,000 not 100,000 B.S. 10,000 not 100,000 N.R.	10 not 100	
3663. Kingston A.B.C. coke effluent. 17/10/05.	—	1,000 not 10,000 B.S. 1,000 not 10,000 B.S.	1 not 10	
3666. Kingston A.B.C. coke effluent. 13/11/05.	—	1,000 not 10,000 B.S. 1,000 not 10,000 N.R.	1 not 10	
B. Kingston A.B.C. coke effluent. 31/1/06.	—	1,000 not 10,000 B.S. 10,000 not 100,000 N.R.	Negative 1 c.c.	
3571. Kingston A.B.C. clinker effluent. 28/11/04.	1,000 not 10,000 (– indol) (+ clot)	10,000 not 100,000 B.S. 10,000 not 100,000 N.R.	1 not 10	
777. Kingston A.B.C. clinker effluent. 3/1/05.	10 not 100 (– indol) (– clot)	10 not 100 B.S. 100 not 1,000 N.R.	Negative 1 c.c.	
782. Kingston A.B.C. clinker effluent. 1/2/05.	1,000 not 10,000 (+ indol) (+ clot)	1,000 not 10,000 B.S. 1,000 not 10,000 N.R.	10 not 100	
3651. Kingston A.B.C. clinker effluent. 17/8/05.	—	10,000 not 100,000 B.S. 10,000 not 100,000 N.R.	1 not 10	
3664. Kingston A.B.C. clinker effluent. 17/10/05.	—	10,000 not 100,000 B.S. 10,000 not 100,000 N.R.	10 not 100	
3667. Kingston A.B.C. clinker effluent. 13/11/05.	—	1,000 not 10,000 B.S. 1,000 not 10,000 N.R.	1 not 10	
(A.) Kingston A.B.C. clinker effluent. 31/1/06.	—	1,000 not 10,000 B.S. 1,000 not 10,000 N.R.	Negative 1 c.c.	
476. Kingston Corporation coke effluent. 2/2/03.	10,000 not 100,000 (+ indol) (+ clot)	1,000 not 10,000 B.S. 1,000 not 10,000 N.R. 10,000 not 100,000 In. 10,000 not 100,000 L.P.M.	1 not 10	"Gas" test+1 c.c. : ·1 c.c. Gelatine (24 hours at 20°C). Number of bacteria (Gelatine at 20°C.) 270,000 per c.c.
3270. Kingston Corporation coke effluent. 26/10/03.	100 not 1,000 (– indol) (+ clot)	100 not 1,000 N.R.	10 not 100	
647. Kingston Corporation coke effluent. 10/12/03.	1,000 not 10,000 (+ indol) (+ clot)	1,000 not 10,000 N.R.	10 not 100	
477. Kingston Candy percolating filter effluent. 2/2/03.	100 not 1,000 (+ indol) (+ clot)	1,000 not 10,000 B.S. 100 not 1,000 N.R. 100 not 1,000 In. 100 not 1,000 L.P.M.	1 not 10	"Gas" test negative 1 c.c. Gelatine (24 hours at 20 °C). Number of bacteria Gelatine at 20 °C.) 1,600,000 per c.c.
526. Kingston Candy percolating filter effluent. 4/5/03.	—	1,000 not 10,000 N.R.	1 not 10	

SUMMARY.

The sewage treated at the Kingston works is mainly domestic, but it contains the waste liquors from two breweries, a tannery, a mineral water manufactory and a large gas-works. Notwithstanding that a large quantity of subsoil water gains access to the sewers, the dry-weather sewage may be regarded as of almost average organic strength, the reason probably being that the strong sewages, which (presumably) result from the separate systems at Surbiton and Hampton Wick, compensate for the surface and subsoil water in the Kingston sewers. Owing to the pumping of all three sewages, both the day and the night flows are of an even character, the rate of flow during the day being about twice that at night. Further, owing to the ejector system in use at Hampton Wick, the sewage from that place apparently takes a considerable time to arrive at the Kingston works, with the result that the combined sewage as a whole remains of comparatively even strength throughout the 24 hours.* This must have a favourable influence on the precipitation process, by conducing to uniformity of working.

Not more than twice the dry-weather flow of sewage is ever treated at the works, any excess over this discharging into the Thames.

There is no grit settlement, the grit being brought down with the other solids in the precipitation process, with evident benefit to the process.

The precipitation tanks are worked in series of two or three tanks each, the sewage receiving continuous-flow settlement in them for about $6\frac{1}{2}$ hours, on the average. The dividing wall in each tank lengthens by about 50 per cent. the distance which the liquid has to travel, but the rate of flow is of course proportionately quickened. An exceptionally large quantity (about 50 grains per gallon) of mixed precipitants are used in the process, the precipitation effected being uniformly excellent ; this result is no doubt due both to the large amount and to the nature of the precipitants employed. The suspended solids left in the precipitation liquor do not exceed 1 to 2 parts per 100,000, as against 31 parts in the hourly samples of sewage examined, and the liquor therefore shows a striking reduction in total organic impurity, when compared with the original sewage. Bacteriologically, some of the samples examined were very good for a precipitation liquor, but the number of bacteria usually present was actually large.

About 20,000 tons per annum of wet sludge (estimated to contain about 90 per cent. of moisture) are produced from an average of about 930,000,000 gallons of sewage, or 21·5 tons per 1,000,000 gallons. This sludge is pressed, broken up, and dried until the moisture is reduced to about 25 per cent., when it is passed through a revolving screen, the resulting fine powder being sold for manure under the name of Native Guano.

The chemical analyses of a sample of this sludge showed it to contain 26 per cent. of moisture, 1·93 per cent. of nitrogen, and 1·74 per cent. of phosphoric acid (equivalent to 3·8 per cent. of tribasic phosphate of lime); judged by its chemical analysis, therefore, the manurial value of this sludge is not high.† Bacteriologically, the sludge was rich in microbial life, but it is probable that the bacteria were present as spores. The fact that no B. coli were found in as much as one gramme of the sludge, and that the presence of nitroso-bacteria could not be demonstrated, makes it unlikely that the agricultural value of this manure is to be attributed to the activity of its bacteria. On the other hand, it is conceivable that the presence of multiple spores of bacteria may assist the rapid decomposition of the sludge and of other organic matter in the surrounding soil, and help in this way to set free substances suitable for plant life. Dr. Somerville, formerly of the Board of Agriculture, has presented to the Commission a ‡ report which gives the results of several series of field experiments on the manurial values of this and other sludges, when applied to crops of mangolds and swedes.

The two contact beds at Kingston which have been under observation for the Commission are only small experimental ones ; they are constructed respectively of coke and clinker, the filtering material being in both cases of small to medium size. As experimental filters, these have treated precipitation liquor at very varying rates, but from July, 1902, to November 10th, 1904, the coke bed received 3 fillings per day of 12 hours,¶ and yielded effluents of consistently good quality from a chemical point of view, while bacteriologically they were above the average in microbial quality for contact bed processes of sewage treatment. There were scarcely any ordinary samples of clinker bed effluent examined, and we are, therefore, unable to express a definite opinion upon these.

* Although we ourselves only examined one sample of night sewage (which was very strong for a night sample), our observations at the works bear out the above statement.

† A second sample of this sludge which was only examined chemically, gave 10·19% of moisture, 2·49% nitrogen, and 2·35% phosphoric acid.

‡ See Appendix VIII. to Fifth Report of Commission.

¶ *Note.*—Four fillings per day from November 10th to 29th, 1904.

The coke bed was started in May, 1898, and the clinker bed in June, 1902. From May, 1898, to November, 1904, *i.e.*, during a period of 6½ years, the coke bed treated an average of 3·52 fillings of precipitation liquor per day, and was once partially renewed (March, 1901). Its capacity at the end was found to be 28·8 per cent. of the original empty tank capacity. During the 2½ years from June, 1902, to November, 1904, the clinker bed treated precipitation liquor at an average rate of 3·2 fillings per day of 12 hours, its capacity at the end of the time being about 40·9 per cent. of the original empty tank capacity, and about 88 per cent. of the original water capacity. This comparatively slow rate of reduction of capacity in both beds is sufficient in itself to prove that the precipitation liquor treated must have been unusually well clarified, both from ordinary suspended and from colloidal solids.

With regard to the later (experimental) samples,—(A)—From November 10th, 1904, to February 21st, 1906, *i.e.*, for fully 15 months, both beds received precipitation liquor at the rate of 6 fillings per 24 hours, the capacity of the coke bed falling from 23·3 per cent. to 19·8 per cent. of the original empty tank capacity, while the capacity of the clinker bed was reduced from 40·9 to 32·6 per cent. During this period of 15 months the coke bed treated precipitation liquor at the rate of 246 gallons per cube yard per 24 hours, and the clinker bed 373 gallons. The experimental effluents from both beds had, on the whole, the usual good appearance of the ordinary effluents from Kingston, but the general results of analysis showed that the purifying capacity of the clinker bed was overtaxed by the very large volume of precipitation liquor treated. The effluents from the coke bed, while not consistently good, were sufficiently so to allow of a further experimental increase to 8 fillings per day, the clinker bed being put back to 4 fillings.

During this second experiment (B), which extended over nearly eight months, the capacity of the coke bed fell from 955 to 630 gallons, the latter figure being equivalent to 15 per cent. of the original empty tank capacity. The capacity of the clinker bed remained practically constant at 1,300 gallons, which is equivalent to 31·5 per cent. of the original empty tank capacity. During this period the coke bed treated precipitation liquor at the average rate of 260 gallons per cube yard, per day, and the clinker bed 214 gallons. The coke bed effluents were again rather the better of the two.

These experimental results, taken in conjunction with the observations on the beds when they were treating 3 fillings of precipitation liquor per day of 12 hours, bear out the point that the volume of sewage liquid which can be treated on a contact bed depends to a very large extent upon the efficiency of the preliminary treatment for the removal of suspended solids; and they show that in the case of a precipitation liquor of the strength of that at Kingston, about 150 to 200 gallons can be treated per cube yard per day, without rapid loss of capacity. Still, however well clarified a precipitation liquor may be, it must always contain a small quantity of suspended and probably also of colloidal solids; hence the filter beds must undergo loss of capacity—in other words, their economic life cannot be prolonged indefinitely, unless the surface material is sufficiently fine to prevent ingress of suspended solids into the body of the bed. From the data obtained in the working of the coke bed at Kingston during the 3 years and 8 months from March 1901, to November 1904, at an average rate of 3·72 fillings per day, the bed had by no means reached its economic limit on the latter date. At a low estimate, it would probably have lasted for a further period of 5 years, at the same rate of working, before the filtering material had to be washed or renewed.

Owing to the different quantities of liquor which have been treated on the coke and clinker beds, and to the slightly different sizes of the material composing them, we are unable to draw any exact deduction with regard to the comparative purifying powers of the coke and clinker. We think, however, that, had the two beds been working under precisely similar conditions, the clinker bed effluent would probably have been as good, or nearly as good, as that from the coke bed.

Excepting at the main inlet channel, where the sewage is stirred by the recording water wheels and where some slight local smell is noticeable, the precipitation process at Kingston is carried on with little or no smell. In the vicinity of the storehouse for the Native Guano, however, there is often a characteristic odour of the dried sludge, which might be objected to by houses in the immediate neighbourhood.

For much help in connection with our work at Kingston we should like to express our thanks to Mr. Douglas Archibald; Mr. J. Stevens, Manager of the Sewage Works; Mr. Lloyd, Chemist to the Works; Mr. W. Stevens, Secretary to the Native Guano Company; Major Henry Macaulay, Borough Surveyor of Kingston; and Dr. Beale Collins, Medical Officer of Health.

KNOWLE SEWAGE WORKS.

(Bristol City Corporation.)

1. Situation of works - - - - - - -	At Knowle.—$2\frac{1}{4}$ miles from the centre of Bristol.
2. Method of treatment - - - - -	Closed septic tank, followed by percolation through rather coarse material (Stoddart's distributors used).
3. Population draining to works during observation	1,600.
4. Water supply in gallons per head and whence obtained - - - - - - -	22 gallons; from the Bristol supply—a rather hard water.
5. Number of water-closets - - - - -	
6. Sewerage system - - - - - -	Partially separate.
7. Average dry-weather flow of sewage in gallons per 24 hours - - - - - - -	41,000.
8. Gallons of sewage per head per day - - -	25·6
9. Character of the sewage - - - - -	A domestic water-closet sewage.
10. Period of observations - - - - -	November, 1902, to December, 1904.
11. Age of filters - - - - - - -	2 years and 3 months.
12. Amount of storm water dealt with - - -	A volume up to about 6 times the dry-weather flow.
13. Total capacity of tanks in gallons - - -	26,000
14. Total area of filters in yards super - - -	29.3
15. Total cubic content of filters in yards cube -	58.6
16. Nature of filtering medium - - - -	Coarse, washed destructor clinker.
17. Gallons of septic tank liquor treated per yard super, per 24 hours (all filters included) - -	1,400 to 8,000.
18. Gallons of septic tank liquor treated per yard cube, per 24 hours (all filters included) - -	688 to 4,000.
19. The final effluent is discharged into - - -	The Brislington Brook, a tributary of the River Avon.

FLOW OF SEWAGE.

The flow of sewage was gauged over a period of seven days, in May, 1903.*

Some rain fell on the day previous to the flow measurement, but the ground was quite dry at the time, and its effect upon the sewage flow was not felt after the first day, and only very slightly upon that day. For the rest of the week the weather was dry and hot.

The flows recorded were as follows :—

Monday, May 18th	48,215	gallons per 24 hours.
Tuesday, ,, 19th	44,650	,, ,, ,,
Wednesday, ,, 20th	41,745	,, ,, ,,
Thursday, ,, 21st	39,525	,, ,, ,,
Friday, ,, 22nd	38,010	,, ,, ,,
Saturday, ,, 23rd	39,045	,, ,, ,,
Sunday, ,, 24th	37,015	,, ,, ,,

The weather at the time of our gaugings being dry, we had no opportunity of measuring the wet weather flow over a definite period, but we have made rough measurements of the flow on the occasions of our visits to the works in wet weather, and have consequently been able to form an opinion as to the rate of flow at such times.

Our observations have led us to the following estimates of the sewage flow at Knowle.

	Gallons per 24 hours.
Dry weather flow to works - - - - - - -	41,000
Highest rate of flow in dry weather - - - - - -	63,500
Lowest rate of flow in dry weather - - - - - -	20,700
Highest rate of flow in wet weather - - - - - -	200,000–250,000

Subsoil Water.—A fair quantity of subsoil water appears to gain access to the sewers.

Crude Sewage.—The following samples were examined :—Three sets of hourly samples, Nos. 529, 532 and 535: two ordinary chance samples, Nos. 3120 and 3142 ; and one sample of weak night sewage, No. 538. The hourly samples were taken over the usual three days, in May, 1903, in dry weather, following a very wet day, the weak night sewage being drawn during the third day.

The *Hourly* samples gave the figures :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - - - - -	(3·10 to 5·40)	4·02	(3)
Albuminoid Nitrogen - - - - - - -	(0·61 to 0·78)	0·71	(3)
Total Organic Nitrogen - - - - - - -	(1·54 to 1·93)	1·70	(3)
Total Nitrogen - - - - - - - - -	(4·64 to 7·33)	5·72	(3)
"Oxygen absorbed" from Permanganate at 27°C. (80°F.) *at once*	(1·63 to 1·99)	1·86	(3)
,, ,, ,, ,, ,, *in 4 hours*	(7·50 to 8·42)	8·07	(3)
Chlorine - - - - - - - - - - -	(6·90 to 8·60)	7·67	(3)
Solids in Suspension - - - - - - - -	(17·5 to 21·2)	19·40	(3)
Solids by Centrifuge (vols.) - - - - - - -	(137 to 202)	176	(3)
Ratio of Solids in Suspension to Centrifuge Solids - -	1 : 10·3, 8·9 and 7·8	1 : 9·0	(3)

* Owing to the local conditions, this has been a gauging of the effluent and not of the sewage.

A partial Analysis of the Weak Night Sewage, No. 538, drawn on Thursday, May 21st, 1903, at 3.30 a m. gave :—

	Parts per 100,000.
Nitrous Nitrogen	0·05
Nitric Nitrogen	2·0 approx.
"Oxygen absorbed" at 27° C. (80° F.) *at once*	0·17
" " " " " *in 4 hours*	0·58
Incubator test (by smell)	+
Solids by Centrifuge (vols.)	7·0
c.c. per litre.	
Oxygen in Solution	3·5 approx.

The above figures show the sewage to be one of less than medium strength, though we have to remember that the heavy rain which preceded the drawing of the first day's set of hourly samples probably caused that day's sample to be slightly more dilute than usual. The sample of weak night sewage evidently consisted in great part of subsoil water ; the large amount of nitrate in it is worth noting, and also the fact that it withstood the incubator test.

The two chance samples of sewage, Nos. 3120 and 3142, were only examined partially. They were both drawn when the flow of sewage was swollen by rain, in March and May, 1903. No. 3120 was apparently rather weak, and 3142 of about medium strength, excepting that it contained a considerable quantity of suspended solids, evidently washed out of the sewers by the rain.

Bacteriological Notes.—Six samples were examined bacteriologically. The results are shown in the following table. There are no special points of importance to be noted. All the samples yielded a positive result with $\frac{1}{100000}$th c.c. with the neutral red broth test.

Description of the Sample.	Number of B. coli (or gas-forming coli-like microbes).	B.S.=Bile salt glucose peptone test. N.R.=Neutral red broth test. In.=Indol test. L.P.M.=Lactose peptone milk test.	B. enteritidis sporogenes test.	Remarks.
·3120 Crude sewage - 12/3/03.	—	100,000 N.R.	10 not 100	
·3142 Crude sewage - 4/5/03.	—	100,000 N.R.	100 not 1,000	
·259 Crude sewage - 19/5/03.	—	100,000 N.R.	1,000 not 10,000	
·532 Crude sewage - 20/5/03.	—	100,000 N.R.	100 not 1,000	
·535 Crude sewage - 21/5/03.	—	100,000 N.R.	100 not 1,000	

SEPTIC TANKS.

There are two covered septic tanks, with a total capacity of 26,000 gallons. They are constructed of cement concrete and provided with special outlets, midway between the roof and the floor of the tank, for the purpose of drawing off the tank liquor, when the tanks are sludged.

The tanks are used in series.

Flow through.—In dry weather, with a sewage flow of 41,000 gallons per 24 hours, the flow through the tanks would be about once in 15·2 hours, at a rate of ½ inch per minute. In storm times, with a flow of 200,000 gallons per 24 hours, the flow through would be once in 3·2 hours.

Cleaning.—Between June 23rd, 1900, when the tanks were first used in the present way, and December 16th, 1904, the tanks were cleaned out four times, viz. :—

(1) January, 1901.
(2) April, 1902.
(3) August, 1903.
(4) December, 1904.

On each occasion the operation took about one week.

During the observations the tanks were twice cleaned,—in August, 1903, and in December, 1904, when the works were dismantled. On this last occasion, after the tanks had run for 16 months, No. 1 was quite full of thick sludge, while No. 2 was about half full of fairly thick sludge, and there is no doubt that the tanks had been in need of cleaning for some time. In any estimate, therefore, of the work done either by the tanks or the filters during the latter part of our observations, this fact must be specially borne in mind.

This final cleaning was carried out as follows :—By mixing the sludge from the second tank with that in the first, the whole was rendered just liquid enough to flow to a chain pump, which had been erected temporarily, neither tank being fitted with sludge valves. In this way, the greater portion of the sludge was removed in 8 days. When the sludge would no longer flow to the pump, the remainder was removed in buckets filled by hand and lifted by a windlass. This took 3 days.

The sludge was tipped in its semi-liquid state over about 4 acres of the steep grassy slopes on either side of the works, and it lay there until dry. The weather being fine at the time, it dried rapidly.

The whole operation took 11 days, and although there was some smell it did not appear to be great.

Septic Tank Liquor.—Three sets of hourly samples and twelve chance samples have been examined chemically.

The *hourly* samples, Nos. 530, 533 and 536, drawn at the same time and under the same conditions of weather as the hourly samples of sewage, were remarkably even in composition. They gave the following figures :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(3·29 to 3·72)	3·46	(3)
Albuminoid Nitrogen	(0·51 to 0·55)	0·52	(3)
Total Organic Nitrogen	(1·30 to 1·37)	1·33	(3)
Total Nitrogen	(4·61 to 5·02)	4·79	(3)
"Oxygen absorbed" at 27° C (80° F.) *at once*	(1·36 to 1·61)	1·46	(3)
,, ,, ,, ,, *in 4 hours*	(5·30 to 5·85)	5·62	(3)
Chlorine	(7·50 to 7·96)	7·71	(3)
Solids in Suspension	(7·20 to 10·35)	8·42	(3)
Solids by Centrifuge (vols.)	(60 to 91)	74·0	(3)
Ratio of Solids in Suspension to Centrifuge Solids	(1 : 8·8, 9·1, and 8·3)	1 : 8·7	(3)

These hourly samples of septic tank liquor were not very strong. The figures of analysis do not differ very greatly from those of the hourly samples of sewage, excepting as regards suspended solids; the suspended solids—at the time rather large in amount—were finely divided. The following figures give the percentage reduction in the tank liquor.

Albuminoid Nitrogen	27	per cent. reduction.
Total Nitrogen	16	,, ,,
"Oxygen absorbed" *in 4 hours*	29	,, ,,
Suspended Solids	75	,, ,,

The twelve chance samples examined chemically (Nos. 3069, 3083, 3121A, 3138, 3143, 3556, 3559, 3561, 3565, 3567, 3572, and 3580) were drawn at different times of the

winter and spring months, but the last seven of them in November and December, 1904. Two-thirds of them were taken in dry weather. They gave the following figures :—

	Parts per 100,000.	Average.	Number of estimations.
Ammoniacal Nitrogen	(1·48 to 6·99)	4·40	(8)
Albuminoid Nitrogen	(0·27 to 1·32)	0·75	(8)
Total Organic Nitrogen	(0·78 to 2·19)	1·57	(7)
Total Nitrogen	(4·79 to 9·19)	6·32	(11)
Oxygen absorbed at 27° C (80° F)—*at once*	(1·73 to 3·36)	2·23	(12)
„ „ „ *in 4 hours*	(4·39 to 12·50)	7·43	(12)
Chlorine	(6·24 to 9·66)	7·96	(6)
Solids in Suspension	(5·9 to 22·4)	13·0	(6)
Solids by Centrifuge (vols.)	(37·0 to 146·0)	96·0	(12)
Ratio of Solids in Suspension to Centrifuge Solids	{1 : 5·9, 9·5, 8·9, 9·9, 18·0, 6·5}	1 : 9·8	(6)

These chance samples, unlike the hourly ones, necessarily varied greatly in composition; but, taking the whole of them together, they were distinctly stronger than the hourly samples. The following points, among others, are worthy of note :—

1. In times of storm very considerable quantities of nitrite and nitrate may be present in this liquor (1·03 nitrous and nitric nitrogen in No. 3143 and 0·77 in No. 3580).

2. The suspended solids issuing from the tank varied between the wide limits of 5·9 and 22·4, the latter figure being obtained from No. 3580, which was drawn when there was a very heavy flow of sewage, owing to rain.

Bacteriological Notes.—Eleven samples were examined bacteriologically and the results are shown in the accompanying table. The samples usually contained 100,000 B. coli or coli-like microbes per c.c. The bile-salt glucose peptone and neutral red broth tests usually gave a positive result with $\frac{1}{100000}$th of a cubic centimetre. The B. enteritidis sporogenes test usually gave a positive result with $\frac{1}{100}$th to $\frac{1}{1000}$th c.c.

Description of the Sample.	Number of B. coli (or gas-forming coli-like microbes).	B.S. = Bile salt glucose peptone test. N.R. = Neutral red broth test. In. = Indol test. L.P.M. = Lactose peptone milk test.	B. enteritidis sporogenes test.	Remarks.
3069 Septic liquor - 26/11/02.	100,000 (+indol) (+clot)	100,000 In. 100,000 N.R. 100,000 L.P.M. 100,000 B.S.	1,000 not 10,000	
3121A Septic liquor - 12/3/03.	—	100,000 N.R.	100 not 1,000	
3143 Septic liquor - 4/5/03.	—	100,000 N.R.	10 not 100	
530 Septic liquor - 19/5/03.	—	100,000 N.R.	1,000 not 10,000	
533 Septic liquor - 20/5/03.	—	100,000 N.R.	100 not 1,000	
536 Septic liquor - 21/5/03.	—	100,000 N.R.	100 not 1,000	
3556 Septic liquor - 2/11/04.	100,000 (+indol) (+clot)	100,000 B.S. 100,000 N.R.	1,000 not 10,000	
3559 Septic liquor - 3/11/04.	100,000 (−indol) (−clot)	10,000 B.S. 10,000 N.R.	100 not 1,000	
3561 Septic liquor* - 16/11/04.	100,000 (+indol) (+clot)	100,000 B.S. 100,000 N.R.	100 not 1,000	
3567 Septic liquor* - 21/11/04.	100,000 (+indol) (+clot)	100,000 B.S. 100,000 N.R.	1,000 not 10,000	
3572 Septic liquor* - 30/11/04.	100,000 (+indol) (+clot)	100,000 B.S. 100,000 N.R.	100 not 1,000	

* Special samples.

FILTERS.

Number of filters, 2.

Size of each, 22 feet by 6 feet by 6 feet deep.

Total area, 29·3 square yards.

Total cubic content, 58·6 cube yards.

Construction.—Each filter is laid on a sloping concrete bottom and is entirely enclosed by brick walls, except that on three sides of each the bottom layer of bricks is laid on the alternate brick and space plan, to allow the effluent to flow out from the filter and to create an air current through the filtering material.

Material.—Washed destructor clinker of about 3 inches diameter, except at the bottom where still larger material is used.

Distribution.—The distribution of the tank liquor over the 29.3 square yards of surface is effected by means of 14 Stoddart Patent distributors, which may be described as follows: The distributors consist of galvanised iron sheets, stamped into a corrugated form which resembles a succession of V's. Diamond-shaped holes are punched on the crests of these V's and small holes in their lower angles carry the drip points (360 per square yard) which hang from the under side.

The distributors are fed either from one or both ends, preferably the latter, and fit into recesses provided in specially designed cast-iron channels.

The liquid on entering the V-shaped channels rises to the level of the crest slots, flows through them and down the under side of the distributors till it reaches the drip points, whence it falls on to the filter. The distributors are each 1 square yard in area, and at Knowle are expected to feed 2 square yards of filter.

Age.—The filters were first brought into use in August, 1900.

Working.—Until there is need of brushing the accumulated solid matter out of the trays, the tank liquor simply passes on to the filter in all its varying rates of flow and without intermittence. When it becomes necessary to clean the distributors and channels, the liquor is diverted for a few minutes on to a sand filter, and the accumulation in the channels is brushed into it as it flows there. At Knowle the operation is carried out once a week, and takes about 15 minutes.

Amount of septic liquor treated.—

Per square yard—

In dry weather - - - - -	1,400	gallons per square yard per 24 hours.
In wet weather, about - -	8,000	,, ,, ,, ,,
Probable average amount - -	2,000	,, ,, ,, ,,

Per cube yard—

In dry weather - - - -	688	gallons per cube yard per 24 hours.
In wet weather, about - -	4,000	,, ,, ,, ,,
Probable average amount - -	1,000	,, ,, ,, ,,

Effluents.—Three sets of hourly samples were examined in May, 1903, viz. Nos. 531, 534 and 537. These gave the following results :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - - - - -	(3·07 and 3·31)	3·19	(2)
Albuminoid Nitrogen - - - - - - - -	(0·38 and 0·29)	0·34	(2)
Oxidized Nitrogen (approximate figures) - - - -	(0·59 to 1·46(?)	0·90	(3)
Total Nitrogen - - - - - - - - - -	(3·88 to 4·24)	4·00	(3)
"Oxygen absorbed" at 27° C. (80° F.) *at once* - - -	(0·74 to 0·96)	0·84	(3)
,, ,, ,, ,, *in 4 hours* - -	(2·25 to 2·92)	2·70	(3)
Chlorine - - - - - - - - -	(7·66 to 8·10)	7·84	(3)
Solids in supension - - - - - - -	(2·20 to 4·92)	3·77	(3)
Solids by centrifuge (vols.) - - - - - - -	(34·0 to 74·0)	53·0	(3)
Ratio of solids in supension to centrifuge solids - - -	(1 : 15·0, 12·1, and 15·5)	1 : 14·2	(3)
Incubator test (Scudder) - - - - - - - -	2 + 1 —		(3)
Incubator test (by smell) - - - - - - - - - -	3 —		(3)
Smell of sample when drawn - - - - - - - -	3 —		(3)
Smell of sample when analysed - - - - - - - -	3 —		(3)

It is obvious from the above figures that these hourly samples of effluent, which were of fairly uniform composition, were not very highly purified. The figure for suspended solids (3·77) is somewhat below the actual amount, because these solids were to some extent kept back in the gauge dam during the gauging. A sample of the solids, thus settled out, was found to contain, after drying, 1·83 per cent. of nitrogen ; they were very flocculent in character, and were, of course, putrescent.

Comparing these hourly samples of effluent with the hourly samples of sewage and of septic tank liquor, we get the following reduction in figures :—

	Sewage.	Septic Liquor.
Calculated on " Oxygen absorbed " in 4 hours —	67 per cent.	52 per cent.

In addition to the hourly samples of effluent, twelve ordinary chance samples and five experimental samples were examined. The ordinary samples may be roughly separated into two divisions, the first of these comprising Nos. 3070, 3084, 3121B, 3138A, 3143A, 613, 3278, and 3340 (partially settled). These eight samples were drawn between November, 1902, and December, 1903, in Spring, Autumn and Winter; three-fourths of them were taken during or shortly after wet weather. They gave the following figures on analysis :—

	Parts per 100,000.	Average.	Number of estimations.
Ammoniacal Nitrogen	(0·63 to 4·06)	2·14 approx.	(5)
Albuminoid Nitrogen	(0·15 to 0·39)	0·25	(3)
Oxidized Nitrogen	(0·32 to 1·86)	1·20	(8)
Total Nitrogen	(2·38 to 5·40)	4·21	(3)
" Oxygen absorbed " at 27° C. (80° F.) *at once*	(0·60 to 1·10)	0·82	(8)
,, ,, ,, ,, *in 4 hours*	(2·01 to 3·39)	2·66	(8)
Dissolved Oxygen taken up in 24 hours at about 18° C. (65° F.)	{0·46, 0 67, 0·68 and over 1·66}	0·87 approx.	(4)
Chlorine	(4·50 to 7·70)	5·95	(3)
Solids in Suspension	(4·6 to 7·4)	5·5	(4)
Solids by Centrifuge (vols.)	(41·0 to 64·0)	52·0	(8)
Ratios of Solids in Suspension to Centrifuge Solids	{1: 8·5, 8·7, 8·9 and 10·0}	1 : 9·0	(4)
Incubator Test (Scudder)		2 + 4 —	(6)
Incubator Test (by smell)		5 + 3 —	(8)
Smell of Sample when drawn		6 + 2 —	(8)
Smell of sample when analysed		8 +	(8)

As compared with the tank liquors (hourly and chance samples), these effluents show the following reduction in figures :—

Calculated on :—	Hourly.	Chance.
" Oxygen absorbed " *at once*	44 per cent.	63 per cent.
" Oxygen absorbed " *in 4 hours*	53 ,,	64 ,,
Suspended Solids (4 effluents)	35 ,,	58 ,,

Considering that practically all the above effluents were unsettled, containing as they did an average of five to six parts of suspended solids, the figures of analysis show the liquid portion to have been of fair quality. All of the eight had an inoffensive smell when they came to be analysed, although three of them failed to withstand the incubator test. Had the solids been well settled out—possibly a difficult matter because of their flocculent character—the effluents would as a whole have probably passed a reasonable standard of purity.

If we compare the permanganate figures given by the effluents, 3070, 3084, 3121B, 3138A and 3143A with those of the corresponding tank liquors 3069, 3083, 3121A, 3138 and 3143, we find the average to be :—

———	Tank Liquors.	Effluents.	Percentage reduction.
"Oxygen absorbed" *at once* - - - -	1·90	0·82	57 per cent.
,, ,, *in 4 hours* - - -	5·47	2·66	51 ,,

DISSOLVED OXYGEN TAKEN UP BY EFFLUENT.

The following figures (all in parts per 100,000) are also of interest :—

———	Sample No. 3143A.	Sample No. 3278.	Sample No. 3340.	Sample No. 3413.
"Oxygen absorbed" *at once* - - - - -	0·80	0·80	0·61	1·32
Dissolved Oxygen taken up in 24 hours at 18°—19° C. - - - - - - -	0·68	0·67	0·46	2·28 + x
"Oxygen absorbed" *in 4 hours* at 27° C. - - -	2·61	2·47	2·01	5·81

In the first three of these effluents, which were fairly well purified and non-putrescible, the dissolved oxygen taken up in 24 hours was about one-fourth of the "oxygen absorbed" in 4 hours; in the last effluent—a poor one—it was something like one-half.

The remainder of the *Ordinary Effluents*, viz., Nos. 3413, 3557, 3558 and 3560, which were collected—the first in March, and the last three on November 2nd and 3rd, 1904—showed a marked falling off, as is evident from the following figures :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - - - -	(5·50 to 6·87	6·01	(4)
Albuminoid Nitrogen - - - - - - - -	(0·51 to 1·24)	0·71	(4)
Oxidized Nitrogen - - - - - - - - -	——	0·0	(3)
"Oxygen absorbed" at 27° C. (80° F.) *at once* - - -	(1·18 to 1·55)	1·37	(4)
,, ,, ,, ,, *in 4 hours* - -	(4·81 to 6·22)	5·57	(4)
Dissolved Oxygen taken up at about 18° C. *in 24 hours* -	(2·28 + x) to 6·01)	3·69 approx.	(4)
Chlorine - - - - - - - - - - -	(8·56 and 11·76)	—	(2)
Solids in Suspension - - - - - - -	(7·5 and 10·1)	—	(2)
Solids by Centrifuge (vols.) - - - - - -	(64·0 to 116·0)	8·40	(3)
Incubator test, by smell - - - - - - - - - -		4 –	(4)
Smell of sample when drawn - - - - - - - - -		1 (?) 3 –	(4)
Smell of sample when analysed - - - - - - - -		1 + 2 –	(3)

These four effluents were very unsatisfactory. Even allowing for the fact that the tank liquors corresponding to the last three of them were stronger than the average of the chance samples of tank liquor generally, it is evident that at this time the filter was very much overtaxed.

The unsatisfactory character of the effluents is further shown by a comparison of the figures for absorption of *dissolved* oxygen in 24 hours at 18° C., (a) by the original sample of effluent and (b) by the sample after filtration through paper :—

———	No. 3557.	No. 3558.	No. 3560.
Original Effluent - - - - - - - - -	6·01	3·02	3·45
Effluent after paper filtration - - - - - - -	2·55	2·27	1·83

The figures given by the filtered effluents are still very high. They show, of course, a great diminution upon those of the original effluents—probably a diminution greater than would be due to the removal of the solids alone ; for the paper filtration of a turbid effluent, in which the solids are slimy and not well coagulated, has the effect of keeping back not merely those solids, but large numbers of bacteria also. For practical purposes, therefore, this comparison is better made between the original effluent and the same effluent after, say, two hours' settlement.

Bacteriological Notes.—Sixteen samples of filter effluent, including three experimenta samples, were examined bacteriologically ; also one sample of effluent solids. The results are shown in the accompanying table. The samples usually contained 100,000 B. coli or coli-like microbes per c.c. The presumptive tests for B. coli commonly gave a positive result with $\frac{1}{100000}$ c.c. As regards the B. enteritidis sporogenes test, out of 16 samples, 5, 9, and 2 yielded positive results with $\frac{1}{1000}$th, $\frac{1}{100}$th and $\frac{1}{10}$th c.c. respectively. The effluents were unsatisfactory from the bacteriological point of view.

Description of the Sample.	Number of B. coli (or gas-forming coli-like microbes).	B.S.=Bile salt glucose peptone test. N.R.=Neutral red broth test. In.=Indol test. L.P.M.=Lactose peptone milk test.	B. Enteritidis sporogenes test.	Remarks.
3070 Filter Effluent - 2611/02.	100,000 (+ indol) (+ clot)	100,000 In. 100,000 N.R. 100,000 L.P.M. 100,000 B.S.	100 not 1,000	
3084 Filter Effluent - 20/12/02.	—	10,000 not 100,000 N.R. 10,000 not 100,000 L.P.M. 1,000 not 10,000 B.S.	100 not 1,000	
3121B Filter Effluent- 12/3/03.	—	10,000 not 100,000 N.R. 10,000 not 100,000 L.P.M.	100 not 1,000	
3153A Filter Effluent- 4/5/03.	—	10,000 not 100,000 N.R.	10 not 100	
531 Filter Effluent - 19/5/03.	—	100,000 N.R.	100 not 1,000	
534 Filter Effluent - 20/5/03.	—	10,000 N.R.	1,000	
537 Filter Effluent - 21/5/03.	—	100,000 N.R.	100 not 1,000	

Description of the Sample.	Number of B. coli (or gas-forming coli-like microbes.	B.S.=Bile salt glucose peptone test. N.R.=Neutral red broth test. In.=Indol test. L.P.M.=Lactose peptone milk test.	B. Enteritidis sporogenes test.	Remarks.
613 Filter Effluent - 5/10/03.	100,000 (– indol) (+ clot)	100,000 N.R.	100 not 1,000	
3340 Filter Effluent, partially settled, 17/12/03.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000, N.R.	100 not 1,000	
3413 Filter Effluent, partially settled, 2/3/04.	100,000 (+ indol) (+ clot)	100,000 N.R.	1,000 not 10,000	
3557 Filter Effluent - 2/11/04.	(100,000) (+ indol) (+ clot)	100,000 N.R. 100,000 B.S.	1,000 not 10,000	
3560 Filter Effluent - 3/11/04.	100,000 (– indol) (+ clot)	100,000 N.R. 100,000 B.S.	10 not 100	
3558 Filter Effluent - 2/11/04.	100,000 (+ indol) (– clot)	100,000 B.S. 10,000 N.R.	100 not 1,000	
3562 Filter Effluent * 16/11/04.	100,000 (– indol) (+ clot)	100,000 B.S. 100,000 N.R.	100 not 1,000	
3566 Filter Effluent * 16/11/04.	100,000 (– indol) (+ clot)	100,000 B.S. 10,000 N.R.	1,000 not 10,000	
3573 Filter Effluent * 30/11/04.	100,000 (+ indol) (+ clot)	100,000 B.S. 10,000 N.R.	1,000 not 10,000	
[539 Sample of sediment from Effluent from percolation filter, settled in bottom of gauge dam, 24/5/03.]*	—	[100,000 N.R.]	[100 not 1,000]	

Effect of temperature on the filters.—The temperature observations at Knowle have shown that the temperatures of the sewage liquids are only slightly affected by the temperature of the atmosphere. The lowest effluent temperature recorded (during a slight frost) was 8° C.

There can be no doubt, we think, that the plan of building a percolating filter below the surface of the ground serves to protect it from cold, and it may be useful to point out that the probable reasons for the evenness of temperature maintained by the Knowle filter effluent are :—

(1) That the filter is built below the surface of the ground, and

(2) That the surface of the filter is well shielded by the high boarding which encloses the works.

We have, however, had no opportunity of making temperature observations at Knowle in severe weather.

* Special experimental samples.

Experiment on reduction of flow.—It was hardly to be expected that the filter would produce an effluent of high class when dealing with the very large quantities of septic tank liquor usually passed on to it. It was thought advisable, therefore, to make an experiment with reduced flows, in order to see at what stage a non-putrescible and satisfactory effluent would be obtained.

At the time when it became possible for us to make this experiment, we were notified of the approaching abandonment of the Knowle works, and our operations had consequently to be hurried. For the purpose of the experiment we should have wished the septic tank to have been cleaned out, and the filter to have been given a complete rest before starting anew with the reduced flow. As it was, the tank was very full of sludge, and the filter was somewhat ponded on the surface. In drawing any conclusions from the results, therefore, the state of the tank and of the filter must be borne in mind.

Before reducing the flow, we drew some samples, to ascertain the degree of purification which the filters were then effecting. The results of the analysis of these samples have already been given along with others (tank liquors Nos. 3556 and 3559 and effluents Nos. 3557, 3558 and 3560), but they may be repeated separately here.

Parts per 100,000.	No. 3556. Tank Liquor. Drawn Wed. Nov. 2nd, 1904, 11.30 a.m.	No. 3557. Effluent. Drawn Wed. Nov. 2nd, 1904, 11.35 a.m.	No. 3558. Effluent. Drawn Wed. Nov. 2nd, 1904, 10 p.m.	No. 3559. Tank Liquor. Drawn Thurs. Nov. 3rd, 1904, 6 a.m.	No. 3560. Effluent. Drawn Thurs. Nov. 3rd, 1904, 6.5 a.m.
Ammoniacal Nitrogen - - - - -	6·99	5·90	6·87	5·50	5·78
Albuminoid Nitrogen - - - - - -	1·32	0·54	1·24	0·64	0·51
Oxidized Nitrogen - - - - - - -		0·0	0·01		0·0
Total Organic Nitrogen - - - - - -	1·90			1·37	
Total Nitrogen - - - - - - -	8·89			6·87	
"Oxygen absorbed" at 27°C *at once* - -	2·77	1·41	1·55	2·29	1·18
" " at 27°C *in 4 hours* - -	8·58	5·44	6·22	6·71	4·81
Dissolved Oxygen taken up in 24 hours at 18° C.		6·01	3·02		3·45
Chlorine - - - - - - - -			11·76	8·88	
Solids in Suspension - - - - - -		10·1			
Solids by Centrifuge (vols.) - - - -	93·0		116·0	87·0	64·0
Incubator Test (by smell) - - - -			—		—
Smell of sample when drawn - - - -		—	—		—
Smell of sample when analysed - - - -		—	—		Not noted.

On November 8th, 1904, at 8 a.m., the flow of tank liquor on to the filter was reduced to one half (the normal dry weather flow was 688 gallons per cube

yard*); the weather was wet, a circumstance which militated against the success of the experiment. Eight days atterwards, on November 16th, we drew two samples of tank liquor, Nos. 3561 and 3565, and two of effluent, Nos. 3562 and 3566, in the morning and afternoon. When No. 3562 was drawn, at 11.30 a.m., the flow was at the rate of 570 gallons per cube yard per 24 hours; and when No. 3566 was taken, at 4.30 p.m., the flow was at the rate of 500 gallons.

Thirteen days after this reduction of flow to one-half the normal, we drew, on November 21st at 3 p.m. two further samples, Nos. 3567 and 3568, the day being cold, after a period of dry weather. On this occasion the flow on to the filter was at the rate of 525 gallons per cube yard.

The above six samples gave the following figures on analysis :—

Parts per 100,000	No. 3561. Septic Tank Liquor. Drawn Wed., Nov. 16th, 1904, 11.30 a.m.	3562. Effluent. Drawn, Wed., Nov. 16th, 1904, 11.33 a.m.	3565. Septic Tank Liquor. Drawn, Wed., Nov. 16th, 1904, 4.35 p.m.	3566. Effluent. Drawn Wed., Nov. 16th, 1904, 4.40 p.m.	3567. Septic Tank Liquor. Drawn Mon., Nov. 21st, 1904, 2.55 p.m.	3568. Effluent. Drawn Mon., Nov. 21st, 1904, 3.0 p.m.
Flow on to filter in gallons per cube yard per 24 hours - - - - - -		570		500		525
Ammoniacal Nitrogen - - - - -	5·47	4·60	5·54	4·89		6·00
Albuminoid Nitrogen - - - - -	0·90	1·13 (?)	0·90	0·54		0·66
Oxidized Nitrogen - - - - -		0·29 approx.		0·0		0·09
Total Organic Nitrogen - - - -	2·19		1·26			—
Total Nitrogen -	7·66		6·80		9·19	—
"Oxygen absorbed" at 27° C. *at once* - -	2·21	0·73	2·54	0·36	3·36	1·36
,, ,, ,, *in 4 hours* -	8·59	3·34	8·55	3·85	12·50	5·00
Dissolved Oxygen taken up in 24 hours at 18°C.		0·69		1·36		2·43
Chlorine - - - - - - -		6·40	9·66			8·42
Solids in Suspension - - - - - -	15·6	8·5	13·7	7·6		
Solids by Centrifuge (vols.) - - - -	139·0	90·0	135·0	67·0	132·0	89·0
Incubator Test (by smell) - - - -		—		—		—
Smell of Sample when drawn - - -		+		(?)		+
Smell of Sample when analysed - - -		Slightly –		—		+

* This figure of 688 gallons per cube yard per 24 hours was arrived at from seven days' gauging in dry weather, in May, 1903. The statement that "the flow was reduced to one half" means that it was divided into two equal parts over the whole of the day and night, one part being rejected. Theoretically, half the normal flow would be represented by 344 gallons per cube yard per 24 hours, but owing to variations in flow at different times of the day and to rainfall, the actual volumes often differed widely from this.

On November 24th, at 4 p.m., we further reduced the flow on to the filter to about one-sixth of the total flow of tank liquor, and six days after this (on November 30th) we drew the samples Nos. 3572 and 3573. At the time when these were actually taken, the flow on to the filter was at the rate of 202 gallons per cube yard per 24 hours, but for the five preceding days the filter had only been treating, on an average, 80 gallons per cube yard.

On December 12th, or eighteen days after the reduction of the flow to one-sixth of the normal, we drew our two last samples, Nos. 3580 and 3581. At this time of sampling the flow was at the rate of 770 gallons, being greatly swollen by rain; but for the previous twelve days the average amount treated by the filter was not more than about 160 gallons per cube yard per 24 hours.

These four samples gave the following figures :—

Parts per 100,000.	No. 3572. Septic Tank Liquor. Drawn Wed., Nov. 30th, 1904, 10.35 a.m.	3573. Effluent. Drawn Wed., Nov. 30th, 1904, 10.40 a.m.	3580. Septic Tank Liquor. Drawn Mon., Dec. 12th, 1904, 4.40 p.m.	3581. Effluent Drawn Mon.. Dec. 12th, 1904, 4.45 p.m.
Flow on to Filter in gallons per cube yard, per 24 hours		202		770
Ammoniacal Nitrogen		4·17	2·51	3·00
Albuminoid Nitrogen		0·65	0 62	
Oxidized Nitrogen		0·67	0·77	0·85
Total Organic Nitrogen		0·85	1 80	(?)
Total Nitrogen	6·45	5·68	5·08	4·17
"Oxygen absorbed" at 27° C. (80° F.) *at once*	1·84	1·18	2·20	1·53
" " " " *in 4 hours*	7·19	4·76	9·73	4·47
Dissolved Oxygen taken up in 24 hours at 18°C.		1·53		2·14*
Chlorine	6·24	5·80	6·70	7·96
Solids in Suspension	5·9	17·0	22·4	15·1
Solids by Centrifuge (vols.)	106·0	119·0	146·0	142·0
Incubator Test (by smell)		–		–
Smell of Sample, when drawn		(?)		+
Smell of Sample, when analysed		+		+

As it may be thought worth while to have the chemical figures of all the experimental effluents brought together, they are appended in the following table :—

Table giving the main results of the chemical analysis of the experimental effluents Nos. 3562, 3566, 3568, 3573, and 3581. The figures relate to (a) the

*Temp. went up to 22°C.

original unsettled effluent; (b) the effluent after filtration through paper; (c) the effluent after settlement.

Parts per 100,000.	No. 3562. Original.	No. 3562. Filtered.	No. 3566. Original.	No. 3566. Filtered.	No. 3568. Original.	No. 3568. Filtered.	No. 3573. Original.	No. 3573. Filtered.	No. 3581. Original.	No. 3581. Filtered.	No. 3581. Settled.
Flow on to filter (gallons per cube yard per 24 hours) - - -	570		500		525		202		770		
Ammoniacal Nitrogen - - -	4·60	4·44	4·89	4·82	6·00	6·12	4·17	4·18	3·00	2·62	2·62
Albuminoid Nitrogen - - -	1·13 ?	0·76 ?	0·54	0·32	0·66	0·57	0·65	0·34			
Oxidized Nitrogen - - -	0·29		0·0		0·09		0·67		0·85		
"Oxygen absorbed" at ° 27 C. *at once*	0·73	0·27	0·86	0·37	1·36	0·83	1·18	0·51	1·53	0·50	0·53
,, ,, ,, *in 4 hours*	3·34	1·38	3·85	1·88	5·00	2·99	4·76	2·07	4·47	1·81	2·14
Dissolved Oxygen taken up in 24 hours at 18° C. (65° F.) - -	0·69	0·12	1·36	0·38	2·43	0·75	1·53	1·15	2·14	0·55	1·18
Chlorine - - - - - -	6·40				8·42		5·80		7·96		
Solids in suspension - - -	8·5		7·6				17·0		15·1		
Solids by Centrifuge (vols.) -	90·0		67·0		89·0		119·0		142·0		
Ratio of Solids in Suspension to Centrifuge Solids - - -	1 : 10·6		1 : 8·8				1 : 7·0		1 : 9·4		
Incubator Test (by smell) - -	–	?	–	–	–	–	–	+	–	+	–
Smell of Sample when drawn -	+		?		+		?			+	
Smell of Sample when analysed -	Slightly –		–		+		+			+	

In looking at the figures given by these experimental effluents, it will be seen among other things :—

1. That the purification was in nearly every case insufficient to produce a good effluent, *per se.*, although the last two samples—apart from suspended solids—showed a marked improvement on the others.

2. That the quantity of suspended solids in these (unsettled) effluents, especially in the two last, was excessive.

When the first three samples were drawn, the average flow on to the filter was between 500 and 600 gallons per cube yard per 24 hours ; but when the average flow was reduced to about 200 gallons per cube yard, an appreciable quantity of nitrate appeared in the effluent, and, after filtration through paper, the liquid portion of the effluent withstood incubation.

As the filter had then to be dismantled, we were unable to continue the experiment until the solids washing out of the filter had become more or less normal in quantity. Had this stage been reached, the tank liquor would have had the normal filter to work through, and the effluent generally would no doubt have been of better quality than our two last samples ; further, after the solids had been settled out, the effluent would doubtless have been a non-putrescible one.

So far, therefore, as this experiment went, it indicated that the average flow of so strong a septic tank liquor as that as Knowle on to a 5-foot filter of coarse material ought at all events not to exceed 200 gallons per cube yard per 24 hours.

SUMMARY.

In drawing any conclusions from our observations at Knowle, it has to be borne in mind that the sewage installation there was adapted from earlier works put up for a different method of treatment. It cannot therefore be regarded as strictly typical of the Stoddart process. But subject to this proviso, we submit the following remarks :—

We consider the distribution of the large volumes of tank liquor, which were treated on the filter, to have been efficient. At no time, however, has it appeared to us to be perfect ; for it has frequently been evident that more liquid has passed through one tray than through another, and, further, that the liquid was delivered at different rates through different portions of one and the same tray. On the other hand, we do not think that the distribution has ever been sufficiently at fault to affect the character of the effluent to any marked extent.

On the whole, the distribution was not much affected by wind ; but it has to be noted that the Stoddart trays at Knowle are well sheltered. We have occasionally been sensible of a smell which might be attributed to the method of distribution of the tank liquor, but this was the exception rather than the rule.

When the works were dismantled in December, 1904, after the trays had been in use for four years, we examined the trays carefully and found that they had neither "buckled" appreciably, nor had the galvanising worn off them.

Taking the average of *all* our analyses of the septic tank liquor, the suspended solids issuing from the tank amounted to 10–11 parts per 100,000, the suspended solids in the hourly samples of sewage averaging 19·4 parts. Roughly, therefore, on the basis of these figures, 50 per cent. of the suspended solids of the sewage were held back by the tank. During the two years of our observations the tank was cleaned out twice, but it is obvious from the figures of analysis that either the capacity of the tank should have been greater or that the tank should have been cleaned out more frequently, the rise in suspended solids in the tank liquor being apparent as the tank sludged up.

The filter appears to have been able to deal with the relatively large quantity of suspended matter contained in the tank liquor for the greater part of the time without becoming choked, but towards the end of our observations on its normal working it began to pond badly. It rapidly improved again, however, on reducing the flow, the large quantity of solids washed out after this reduction being very marked. When the filter came to be dismantled, we carefully examined the filtering material (washed destructor clinker) and found it to be in very fair condition.

The effluent throughout our observations contained more suspended solids than it would have been desirable to allow into many streams (approximately 5 to 6 parts per 100,000) ; these were putrescible under laboratory conditions of experiment.

Taking the effluents as a whole (including their suspended solids), they were unsatisfactory (10 out of 15 failed to withstand incubation). Obviously the quantity of tank liquor which was treated on the filter was too large.

As the result of the experimental reduction of flow of tank liquor on to the filter, we came to the conclusion that 200 gallons per cube yard per 24 hours was probably an outside limit of the amount which such a filter could treat successfully day in and day out. Although we have no actual figures on which to base an opinion, other than those which have been already given, we think that it would be safer to place the dry weather flow limit lower than 200 gallons.

The samples usually contained 100,000 B. coli or coli-like microbes per c.c. The presumptive tests for B. coli commonly gave a positive result with $\frac{1}{100000}$ c.c. As regards the B. enteritidis sporogenes test, out of 16 samples, five, nine, and two yielded positive results with $\frac{1}{1000}$th, $\frac{1}{100}$th and $\frac{1}{10}$th c.c. respectively.

Judging from some of the results obtained in connection with percolating filters at other places, this result is to be ascribed to the coarse material in the filter at Knowle and the large amount of liquid treated.

We should like, in conclusion, to express our thanks to Mr. F. Wallis Stoddart, F.I.C., Mr. T. H. Yabbicom, City Engineer of Bristol, and Mr. Griffin, Manager of the Sewage Works, for help in connection with our work at Knowle.

LITTLE DRAYTON SEWAGE WORKS.

Drayton Rural District Council.

1. Situation of works - - - - -	About three-quarters of a mile from Little Drayton.
2. Method of treatment - - - - -	Continuous filtration of grit-settled sewage through a percolating filter of fine material (Ducat process)
3. Population draining to works during observations	1,550 (approximately).
4. Water supply in gallons per head and whence obtained	13·5 gallons; obtained from springs—a fairly soft water.
5. Number of W.C.'s - - - - -	90.
6. Sewerage system - - - - - -	Combined.
7. Average dry weather flow of sewage in gallons per 24 hours	12,000.
8. Gallons of sewage per head per day - -	7·7
9. Character of the sewage - - - -	A very strong slop-water domestic sewage, containing laundry waste.
10. Period of observations at Little Drayton -	March, 1904, to November, 1905.
11. Age of filter - - - - - - -	Part of it six months and part one year old.
12. Amount of storm water treated on the filter during our observations	About 3 times the dry weather flow.
13. Total capacity of tanks in gallons - - -	No tanks are used.
14. Total area of filter in yards super - - -	315.
15. Total content of filter in yards cube - -	787.
16. Nature of filtering medium - - - -	Granite chippings from Ceiriog and Clee Hill.
17. Gallons of settled sewage treated per yard super per 24 hours (based on the average daily flow)	48·5.
18. Gallons of settled sewage treated per yard cube per 24 hours (based on the average daily flow)	19·5.
19. The final effluent is discharged into - -	A ditch which joins the river Tern about 1½ miles below the effluent outfall.

FLOW OF SEWAGE.

The sewerage is on the combined system, and the flow becomes largely swollen with road and roof water in times of storm. There are, however, two overflows on the system, one close to the village and one at the sewage works, but both on the main outfall sewer. The first of these comes into operation when the flow reaches six times the dry-weather flow, but the other diverts the excess of any flow above three times the normal. It may be taken, therefore, that not much more than three times the dry-weather flow ever passes through the two grit chambers or on to the filter.

The flow of sewage was measured continuously for a period of two and a half months in January, February and March, 1905. Part of this period was dry and part wet, so that both dry weather and wet weather flow measurements were taken. In a dry week during January, which was preceded by dry weather, the average flow

amounted to 12,000 gallons per day. This has, therefore, been taken as the dry-weather flow.

From 10 a.m. to 6 p.m. on the majority of the week-days, the flow is of a rather fluctuating character, averaging in rate two or three times the sewage flow of the night or early morning. On Wednesday, which is market-day, the flow in the day hours is large and subject to greater variations, but on Sunday the whole 24 hours' flow is of a very even character. The highest day's flow of 14,700 gallons occurred on the Wednesday of the week, and the lowest day's flow of 10,800 gallons on the Sunday.

The average daily flow throughout the whole 76 days of gauging (January 13th to March 29th, 1905) was 15,350 gallons, or 28 per cent. above the dry-weather flow. The rainfall during this time amounted to 4·65 inches. It is difficult to say how near this figure approaches to an average daily flow throughout the whole year at Little Drayton; but it probably gives a rough idea of the volume and it is therefore included here and used for calculation.

Subsoil Water.—In dry weather the gauge recorded an almost steady night flow at the rate of about 7,000 gallons per 24 hours, or more than half the total dry-weather flow. The whole of this, of course, is not sub-soil water, a considerable quantity being no doubt due to tap leakage; but we think it is to be inferred, both from this and from the fact that the flow of sewage remains much swollen for some days after rain has ceased, that a considerable quantity of subsoil water or ground water finds its way into the sewers.

On Diagram S are given some illustrations of the sewage flow at Little Drayton.

Crude Sewage.—Seven sets of hourly samples, in two series of four and three samples respectively, and two chance samples of night sewage were examined chemically. The reason for drawing two series of hourly samples was that rain and melting snow rendered the first one abnormal, especially as regards suspended solids. The analysis of these is, however, instructive.

The samples of *Series A*, Nos. 3602, 3605, 3609 and 3612, were drawn from Monday, January 23rd, to Friday, January 27th, 1905. Though practically the only rain which fell during this time was 0·08 inch on the second day, much road water from melting snow entered the sewers on the second and third days, and, in a lesser degree, on the first; the fourth day was frosty, and the sewage flow normal.

The chance sample of night sewage, No. 3608, the figures for which are given beside those for the hourly samples, was drawn on Wednesday, January 25th, at 5.30 a.m. It also contained some road water, and the flow was rather greater than usual at that hour.

The following results were obtained:—

Hourly Samples. Series A.	Parts per 100,000.	Average.	Number of Estimations.	Night Sewage, No. 3608.
Ammoniacal Nitrogen	(6·60 and 9·54)	–	(2)	2·34
Albuminoid Nitrogen	1·27 and 1·80)	–	(2)	0·47
Total Organic Nitrogen	(2·72 and 2·64)	–	(2)	1·14
Oxidized Nitrogen		–		0·18
Total Nitrogen	(7·69 to 13·68)	10·72	(4)	3·66
"Oxygen absorbed" at 27° C. (80° F.) *at once*		–		1·66
,, ,, ,, ,, *in 4 hours*	(16·14 to 33·65)	24·18	(4)	5·94
Chlorine		–		5·30
Solids in suspension	(22·5 to 97·4)	52·70	(4)	3·70
Containing mineral matter	(5·3 to 25·4)	16·80	(4)	1·70
Solids by centrifuge (vols.)	(118·0 to 802·0*ap.)	298·0	(4)	26·0
Ratio of solids in suspension to centrifuge solids	(1 : 3·3 to 1 : 8·2)	1 : 6·8	(4)	1 : 7·0

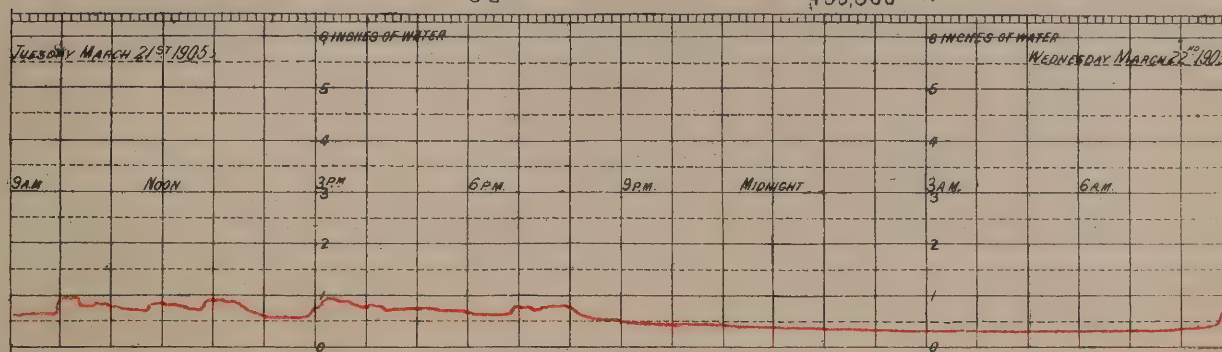
* Ap.=Approximate.

Diagram S.

Diagrams showing flow of Sewage at Little Drayton as falling over a Weir 8" wide.

Note:- Over a Weir 8" wide					
·25 of an inch	=	a rate of	3,456	gallons	per 24 hours.
·50 " " "	=	" " "	9,907	"	" " "
·75 " " "	=	" " "	18,144	"	" " "
1·0 inch	=	" " "	27,864	"	" " "
1·5 inches	=	" " "	50,976	"	" " "
4·0 "	=	" " "	223,200	"	" " "
6·5 "	=	" " "	459,360	"	" " "

DAY.
ALL NIL.



TOTAL FLOW FOR THE 24 HRS = 11,770 GALLONS.

DAY.
DAY)
NIL.

TOTAL FLOW FOR THE 24 HRS = 14,750 GALLONS

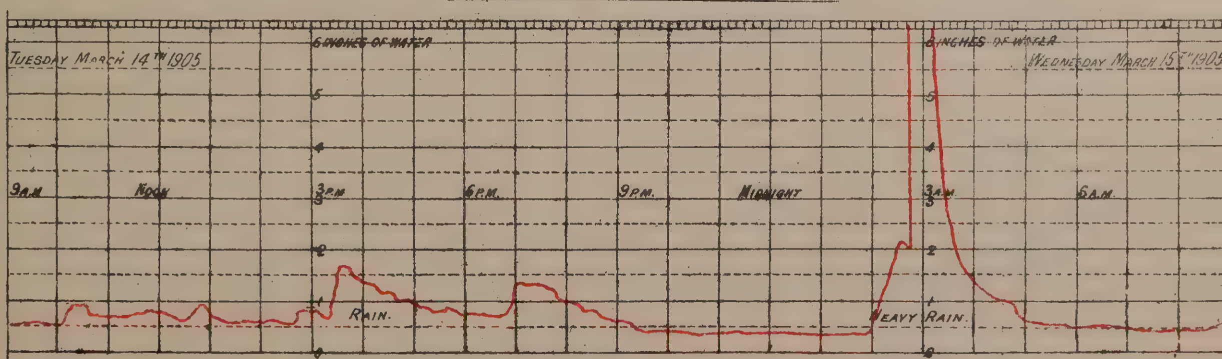
DAY.
LL NIL.

TOTAL FLOW FOR THE 24 HRS. = 11,250 GALLONS

Y DAY.
0·08 INCH.

TOTAL FLOW FOR THE 24 HRS. = 20,370 GALLONS.

13 INCH
ROUND



TOTAL FLOW FOR THE 24 HRS = 28,500 GALLONS.

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As was to be expected from the conditions under which they were drawn, these four sets of hourly samples of crude sewage were very uneven in composition, but they were all strong organically, the sewage being an ammoniacal one and containing much oxidizable matter. The first sample was especially strong and contained as much as 97 parts of suspended solids, no doubt from the washing out of accumulated matter from the sewers. The large quantities of grit and mineral matter in the first three sets is noteworthy, as showing the effect of the road water. The sample of night sewage, No. 3608, was by no means weak, being about half the strength of an average sewage.

Hourly Samples: Series B.—These samples, Nos. 800, 804 and 807, were drawn from Monday, April 10th to Thursday, April 13th, 1905, the rainfall for the three days amounting to 0·15, 0·02 and 0·0 inches respectively. Although the first day's rainfall was a heavy one, the ground must have been rather dry, for the sewage flow was not greatly affected. This series may therefore be taken as representing fairly well the quality of the dry-weather crude sewage at Little Drayton.

The chance sample of night sewage, No. 801, was drawn on Wednesday, April 12th, at 7 a.m.

The following figures were obtained :—

Hourly Samples Series B. Parts per 100,000.		Average.	Number of Estimations.	Night Sewage, No. 801.
Ammoniacal Nitrogen	(6·66 to 8·84)	7·57	(3)	2·89
Albuminoid Nitrogen	(0·99 to 1·86)	1·41	(3)	0·96
Total Organic Nitrogen	(2·30 to 3·20)	2·76	(3)	1·45
Oxidized Nitrogen		0·0	(3)	0·0
Total Nitrogen	(9·86 to 11·14)	10·33	(3)	4·34
"Oxygen absorbed" at 27° C. (80°F.) *at once*	(4·87 to 7·13)	6·13	(3)	1·70
" " " *in 4 hours*	(23·15 to 25·73)	24·44	(3)	5·98
Chlorine	(10·86 to 12·40)	11·40	(3)	6·84
Solids in suspension	(19·4 to 32·2)	23·90	(3)	10·90
Containing mineral matter	(3·3 to 9·5)	6·0	(3)	3·20
Solids by centrifuge (vols.)	(100·0 to 288·0)	181·0	(3)	98·0
Ratio of solids in suspension to centrifuge solids	(1 : 5·0 to 1 : 8·9)	1 : 7·3	(3)	1 : 9·7

The sets comprising this second series were, for a crude sewage from a small township, of fairly even composition, and it will be noted that, excepting in the matter of suspended solids (24 parts), they were almost as strong organically as the *average* of Series A. The second day's sample had much the greatest quantity of suspended matter (32 parts), no doubt because of the large volume of laundry water on that day. The dry-weather crude sewage of Little Drayton, therefore, is very strong both in nitrogenous matter and in oxidizable matter generally, as measured by the "oxygen absorbed" test, though the suspended solids are rather low. As has been already seen, however, when dealing with Series A, the suspended matter is liable to great fluctuations and may at times reach a very high figure.

The chance sample of night sewage drawn at this time, No. 801, was somewhat stronger than the former one, No. 3608.

Bacteriological Notes.—The results of the Bacteriological Examination of the samples of crude sewage are considered under "settled sewage" in a later part of the report.

DETRITUS TANKS.

Number - - - - - - - - - -	**2**
Capacity of each - - - - - - -	**400** gallons
Total Capacity - - - - - - - -	**800** gallons

Construction.—The detritus tanks are small tanks constructed at the top in the form of an irregular hexagon, the sides coming together at the bottom, where a sludge valve is fixed.

Working.—The tanks are used in series, the whole flow of sewage passing through both of them.

Sludging.—In dry weather the tanks are cleaned out about once a week, but in wet weather, owing to the heavy suspended matter brought down in the sewage, it is necessary to clean them out more frequently. The sludge is removed by opening the sludge valve and allowing the whole of the contents of each tank to flow into small sludge lagoons, constructed of earth on the side of the hill. While one tank is being cleaned out, the sewage on its way to the filter is by-passed by means of a side-channel. The operation usually takes about half an hour, and during that time, of course, only one tank is in use.

Owing to the shape of these small detritus tanks, the removal of sludge from them is easy, and is conducted without serious nuisance, but the method of dealing with the sludge cannot be called satisfactory, for the lagoons are small and very roughly constructed. If, owing to wet weather, it becomes necessary to sludge the tanks frequently, the lagoons overflow and the grass land below them becomes wet and sodden with sludge. At such times there is also danger of some sludge or sludge drainage finding its way into the effluent channel, which runs down the side of the hill a little below the lagoons. As there is plenty of land available, this defect in the process could no doubt be easily remedied by digging or ploughing the sludge into a plot specially prepared for the purpose.

Settled Sewage.—The two series of hourly samples of settled sewage, A and B, were drawn at the same time and under exactly the same conditions as the two series of hourly samples of crude sewage. While the figures of analysis of both are given here, Series B will be taken as representing the dry weather flow. In addition, three chance samples of settled sewage were also examined chemically.

Hourly Samples, Series A, Nos. **3603, 3606, 3610** and **3613**.	Parts per **100,000**.	Average.	Number of Estimations.
Ammoniacal Nitrogen - . - -	(5·10 to 10·01)	7·73	(4)
Albuminoid Nitrogen - - - - - - -	(1·25 to 2·20)	1·68	(4)
Total Organic Nitrogen - - - - -	(2·90 to 4·66)	3·46	(4)
Oxidized Nitrogen - - - - - - -	- - - -	0·0	(4)
Total Nitrogen - - - - - - - -	(8·33 to 14·75)	11·21	(4)
"Oxygen absorbed" at 27° C. (80° F.) *at once* - - -	(4·02 to 6·00)	5·15	(4)
,, ,, ,, *in* **4** *hours* - -	(15·71 to 28·57)	22·07	(4)
Chlorine - - - - - - - - - - -	(9·04 to 13·60)	10·96	(4)
Solids in suspension - - - - - -	(16·9 to 45·2)	30·20	(4)
Containing Mineral matter - - - - - - -	(4·0 to 22·2)	10·90	(4)
Solids by centrifuge (vols.) - - - -	(74·0 to 143·0)	106·0	(4)
Ratio of solids in suspension to centrifuge solids - -	(1 : 2·6 to 1 : 4·4)	1 : 3· 7	(4)

The four sets of this series were, like the corresponding sets of crude sewage, Series A, very uneven in composition, from the effect of the road water. They were brown coloured and viscid, with much fine suspended matter, and No. **3606** was noted as

containing some fragments of straw. If contrasted with the crude sewage, they show the following differences in figures :—

Calculated on :—	Reduction.
Total Nitrogen	+ 5 per cent.
"Oxygen absorbed" *in* 4 *hours*	9 " "
Solids in suspension	39 " "
Mineral matter in solids	35 " "
Solids by centrifuge (vols.)	*64 " "

Excepting, therefore, for a reduction of the suspended solids by about 40 per cent., the settlement had made little difference, and the sewage which was sent on to the filter was exceedingly strong organically. It is noteworthy that during the four days, over which the above samples extended, a liquid containing on the average 30 parts of suspended solids per 100,000 (inclusive of 11 parts of mineral matter) was being put upon this comparatively fine grained filter.

Hourly Samples, Series B., Nos. 799, 803 and 806.	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(6·48 to 8·82)	7·54	(3)
Albuminoid Nitrogen	(1·08 to 1·23)	1·16	(3)
Total Organic Nitrogen	(2·41 to 3·17)	2·79	(3)
Total Nitrogen	(9·28 to 11·99)	10·33	(3)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(3·90 to 4·53)	4·18	(3)
" " " " *in* 4 *hours*	(16·63 to 20·65)	18·21	(3)
Chlorine	(10·30 to 13·10)	11·23	(3)
Solids in suspension	(8·90 to 26·00)	19·90	(3)
Containing mineral matter	(4·80 to 6·30)	5·60	(3)
Solids by centrifuge (vols.)	(74·0 to 216·0 approx.)	138·0	(3)
Ratio of solids in suspension to centrifuge solids	(1 : 5·0 to 1 : 8·3)	1 : 7·2	(3)

The three sets of settled sewage comprising Series B. were comparatively uniform in composition. Like the samples of Series A, they were brown in colour and more or less soapy. Comparing them with Series B. of the crude sewage, we find the following differences in figures :—

Calculated on :—	Reduction.
Total Nitrogen	0 per cent.
Albuminoid Nitrogen	1·8 "
Total Organic Nitrogen	0 "
"Oxygen absorbed" *at once*	32 "
" " *in* 4 *hours*	19 "
Solids in suspension	17 "
Mineral matter in solids	10 "
Solids by centrifuge (vols.)	24 "

* This high percentage reduction in the centrifuge figure is the opposite of what one would have expected.

Here, again, the effect produced by the settlement is seen to be comparatively small. At this time the filter had to deal with a concentrated organic liquid containing 20 parts per 100,000 of suspended solids, of which 5·6 parts consisted of mineral matter.

It is thus obvious that the sewage which the Ducat filter at Market Drayton has to treat is exceptionally strong, and also that large quantities of solids, including grit, are allowed to pass on to the filter.

Chance Samples.—The three chance samples of settled sewage examined, Nos. 3420A, 3600 and 3673, were all drawn in the colder months of the year, the first two in dry weather and the last one in wet.

They gave the following results:—

Parts per 100,000.		Average.	Number of Estimations.
Ammoniacal Nitrogen	(2·63 to 7·30)	4·51	(3)
Albuminoid Nitrogen	(0·71 to 1·26)	0·99	(3)
Total Organic Nitrogen	(1·66 to 2·48)	2·03	(3)
Total Nitrogen	(4·59 to 9·78)	6·54	(3)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(2·29 to 3·99)	3·21	(3)
" " " " *in 4 hours*	(11·66 to 24·87)	16·91	(3)
Dissolved Oxygen taken up from water in 24 hours at 18° C.	(12·30) *		(1)
Chlorine	(3·94 to 12·10)	6·99	(3)
Solids in suspension	(40·3 and 46·1)		(2)
Containing mineral matter	(8·8 and 26·1)		(2)
Solids by centrifuge (vols.)	(93·0 to 342·0)	201·0	(3)
Ratio of solids in suspension to centrifuge solids	(1 : 8·5 and 1 : 3·6)		(2)

No. 3420A, drawn at 1.10 p.m., was of about the same strength as the hourly samples of Series B. and contained 40 parts of suspended solids; but the other two samples, Nos. 3600 and 3673, which were drawn at 10.45 a.m. and 10 a.m., were much weaker, excepting for the large quantity of suspended matter in the last sample (46 parts), brought down by the rain. It is evident, therefore, that the strongest sewage reaches the works at Market Drayton at about mid-day. In general character these chance samples resembled the hourly samples which have already been fully described.

Bacteriological Notes.—Fifteen samples of crude and settled sewage were examined bacteriologically. Six out of the fifteen samples yielded positive results with the B. enteritidis sporogenes test with ·001 c.c. (1,000 per c.c.). The majority of the samples yielded positive results with the B. coli test and presumptive tests for B. coli with ·00001 c.c. (100,000 per c.c.).

Description of the Samples.	Number of B. Coli (or gas-forming Coli-like Microbes).	B.S. = Bile salt glucose peptone test. N.R. = Neutral red broth test. In. = Indol test. L.P.M. = Lactose peptone milk test.	B. Enteritidis sporogenes test.	Remarks.
3605. Little Drayton Crude Sewage. 25/1/05.	100,000 (+ indol) (+ clot)	100,000 B.S. 100,000 N.R.	100 not 1,000	
3608. Little Drayton Crude Sewage. 25/1/05.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 B.S. 10,000 not 100,000 N.R.	10 not 100	
3609. Little Drayton Crude Sewage. 26/1/05.	100,000 (+ indol) (+ clot)	100,000 B.S. 100,000 N.R.	100 not 1,000	
3612. Little Drayton Crude Sewage. 27/1/05.	100,000 (+ indol) (+ clot)	100,000 B.S. 100,000 N.R.	1,000 not 10,000	
800. Little Drayton Crude Sewage. 11/4/05.	–	10,000 not 100,000 B.S. 100,000 N.R.	100 not 1,000	

* Sample No. 3673.

Description of the Samples.	Number of B. Coli (or gas-forming Coli like Microbes).	B.S.=Bile salt glucose peptone test. N.R.=Neutral red broth test. In.=Indol test. L.P.M.=Lactose peptone milk test.	B. Enteritidis sporogenes test.	Remarks.
804. Little Drayton Crude Sewage. 12/4/05.	–	100,000 B.S. 100,000 N.R.	1,000 not 10,000	
680. Little Drayton Settled Sewage. 5/5/04.	100,000 (+indol) (+clot)	100,000 N.R.	10 not 100	
3600. Little Drayton Settled Sewage. 17/1/05.	100,000 (+ indol) (+ clot)	100,000 B.S. 10,000 not 100,000 N.R.	100 not 1,000	
3603. Little Drayton Settled Sewage. 24/1/05.	100,000 (+ indol) (+ clot)	100,000 B.S. 100,000 N.R.	1,000 not 10,000	
3606. Little Drayton Settled Sewage. 25/1/05.	100,000 (+ indol) (+ clot)	100,000 B.S. 100,000 N.R.	100 not 1,000	
3610. Little Drayton Settled Sewage. 26/1/05.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 B.S. 100,000 N.R.	1,000 not 10,000	
3613. Little Drayton Settled Sewage. 27/1/05.	100,000 (+ indol) (+ clot)	100,000 B.S. 10,000 not 100,000 N.R.	100 not 1,000	
799. Little Drayton Settled Sewage. 11/4/05.	–	100,000 B.S. 100,000 N.R.	100 not 1,000	
803. Little Drayton Settled Sewage. 12/4/05.	–	10,000 not 100,000 B.S. 100,000 N.R.	1,000 not 10,000	
806. Little Drayton Settled Sewage. 13/4/05	–	100,000 B.S. 10,000 not 100,000 N.R.	1,000 not 10,000	

FILTER.

Number - - - - -	1.
Size - - - - - -	79 feet 4 inches by 35 feet 9 inches.
Area - - - - - -	315 square yards.
Depth of material - - -	7 feet 6 inches.
Total cubic content - -	787 cube yards.

Material.—The filtering material consists of granite chippings from Ceiriog and Clee Hill. It varies in size from $\frac{3}{8}$ to $\frac{3}{4}$ of an inch in diameter, but is of course not by any means spherical in shape.

Construction.—On a concrete bottom which slopes in one direction, a layer of 3-inch agricultural pipes is laid, entirely covering the concrete. Upon this the filtering material rests, being held in position by walls constructed of 4-inch agricultural pipes, laid with a slight dip inwards. These latter pipes are cemented together and supported by six buttressed brick piers on the two sides and two simple brick piers at either end. At the sides of the filter every fourth pipe vertically and every sixth pipe horizontally is carried right through the material, with the object of admitting air into the interior of the bed. The whole filter is enclosed in a brick building with a thatched roof, fitted with a large number of ventilators.

Distribution.—The grit-settled sewage is carried by pipes to small chambers situated at each end of the filter, in which are placed screens of ¼ inch mesh. From these it flows into a small channel constructed on the top of the retaining walls round the four sides of the filter, and subsequently falls over small weirs in the side channels into **32** rows of cast iron tipping troughs, which are supported on the top of the material by means of wooden blocks. In all, therefore, there are **64** troughs in **32** rows; they are laid two feet apart, and each trough tips on both sides.

When the troughs are working well, the distribution is good; but they are rather apt to get out of order if not attended to fairly often, and, as a rule, something like **5** or **6** troughs on an average are found every morning to have stopped tipping. Even in this case, however, the distribution from a trough which has ceased to tip is not entirely bad, owing to the fact that the settled sewage then trickles over the edge and so on to the material underneath. On the whole, therefore, although the troughs require attention for perhaps an hour, at least once if not twice a day, the method may be said to be effective.

Under-draining.—The layer of **3**-inch agricultural pipes completely covering the concrete floor serves for the purpose of underdraining. The effluent is brought by this means to one side of the filter, and is subsequently carried by means of five collecting pipes into a main collecting channel on the outside of the building.

Working.—Since the whole of the filter was brought into use in September, **1903**, it has worked continuously day and night, receiving the whole daily flow of sewage and storm-water sewage up to three times the dry weather flow. Occasionally during this time, part of it (and more especially the part which was brought into use in March, **1903**), has required to be rested and forked, owing to the surface material having become rather choked. Although up to the present time (February, 1906) this need of rest has not presented serious difficulties in working, the occasions for it are undoubtedly becoming more frequent; and from the fact that considerable pooling has been observable on various parts of the surface during **1905**, there can be no doubt that the filter is approaching a time when it will be necessary to wash or renew a few feet of the upper material. At the end of our observations, in November, **1905**, the filter could be kept in fairly good working order by constant digging and raking of the surface; but the advisability of this has appeared to us somewhat doubtful, in view of the condition of the top foot of the material, as it may tend to allow the suspended matter, which is responsible for the local clogging of the surface, to penetrate further into the bed. As an expression of opinion, we should say that it will probably be necessary to wash or renew the upper part (possibly **3** feet) of the material after the winter of **1906–7**, that is, after about **4** years working.

Amount of Settled Sewage treated by the Filter.—On the basis of an average daily flow of **15,350** gallons, the following quantities are treated:—

Per square yard per **24** hours	- -	**48·5** gallons.
Per cube yard per **24** hours	- - -	**19·5** gallons.

On the basis of a dry weather flow of **12,000** gallons per day, the quantities are:—

Per square yard per **24** hours	- -	**38** gallons.
Per cube yard per **24** hours	- - -	**15·2** gallons.

Unsettled Effluents.—Seven sets of hourly samples (in two series, *A* and *B*) and four chance samples were examined chemically, three of the hourly and three of the chance samples being analysed both in their original state and after separation of the suspended solids by filtration through paper or by settlement. The hourly samples were of course drawn at the same time as the hourly samples of crude and settled sewage.

They gave the following figures on analysis. *Series A.*—Nos. 3604, 3607, 3611* and 3614. Drawn January 23rd to 27th, 1905.

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(0·91 to 1·51)	1·20	(4)
Albuminoid Nitrogen	(0·21 to 0·49)	0·31	(4)
Total Organic Nitrogen	(0·68 to 1·76)	1·17	(4)
Oxidized Nitrogen	(3·00 to 4·28)	3·57	(4)
Total Nitrogen	(5·09 to 7·42)	5·94	(4)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(0·62 to 1·56)	0·92	(4)
" " " " *in 4 hours*	(2·29 to 5·99)	3·64	(4)
Dissolved Oxygen taken up in 24 hours at 18° C.	(0·93 to over 3·16)	2·02 approx.	(4)
Incubator Test (Scudder)		4 passed	(4)
" " (by smell)		4 passed	(4)
Smell when drawn		4 good	(4)
Smell when analysed		4 good	(4)
Chlorine	(8·28 to 11·46)	9·88	(4)
{Solids in suspension	(2·70 to 15·60)	7·70	(4)
{Containing Mineral Matter	(2·10 to 9·90)	4·70	(4)
Solids by Centrifuge (Vols.)	(34·4 to 96·0)	52·0	(4)
Ratio of Solids in suspension to centrifuge solids	(1 : 6·2 to 1 : 12·7)	1 : 7·9	(4)
c.c. per litre.			
Oxygen in Solution when analysed	(1·75 and 3·65)		(2)

In discussing the results of the analysis of the effluents, it is necessary to bear in mind that they had undergone no settlement of suspended solids. Considering the variations in strength of the on-going sewage, these effluents—apart from suspended solids—were fairly uniform in composition. In appearance the effluents were of a brownish tint, and—excepting the last sample—they all contained large quantities of suspended matter (average 7·7 parts). They had a clean smell, both when drawn and when analysed, and readily withstood incubation, but on the other hand they took up an average of 2 parts by weight of dissolved oxygen in 24 hours, *i.e.*, a large quantity (for dissolved oxygen absorption by effluents from which the solids had been filtered off); the permanganate absorption figures were also very high. The ammonia of the settled sewage had been well oxidized in its passage through the filter, only 1·2 parts of ammoniacal nitrogen being left in the effluents, together with 3·6 parts of nitric nitrogen; on the other hand, the organic nitrogen still present was very high (fully 1 part). Three of the four samples contained appreciable quantities of nitrite both before and after incubation—a sign that oxidation of the organic matter had not been carried to its fullest extent.

The above samples may therefore be described as well oxidized effluents from a very strong sewage (the flow of which at the time was very uneven), but requiring settlement of their suspended matter. It is interesting to note here that the amount of suspended solids in the four effluents rises and falls with the amount going on to the

* When No. 3611 was drawn, the surface of the filter had ponded in some places.

filter in the corresponding sewages, though, of course, not in anything like an even ratio, thus :—

—	Suspended Solids in :—	
	Sewage.	Effluent.
1st day - - - - - -	35·5	5·7
2nd „ - - - - - -	45·2	15·6
3rd „ - - - -	23·3	6·6
4th „ - - - - - -	16·9	2·7
TOTALS - -	120·9	31·6

The same applies to the mineral matter in the suspended solids, thus :—

—	Mineral matter in Suspended solids in :—	
	Sewage.	Effluent.
1st day - - - - - -	6·7	2·9
2nd „ - - - - - -	22·2	9·9
3rd „ - - - - - -	10·5	3·7
4th „ - - - - - -	4·0	2·1
TOTALS - -	43·4	18·6

No conclusive deductions as to the ultimate choking-up of a filter can be drawn from a few observations, but, so far as the above figures go, they are instructive.

Compared with the samples of settled sewage of Series A, these effluents of Series A show the following reduction in figures :—

Calculated on :—	Reduction, per cent.
Total Nitrogen - - - - - - - - - - -	47
Ammoniacal Nitrogen - - - - - - - -	84
Albuminoid Nitrogen - - - - - - - - -	82
Total Organic Nitrogen - - - - - - - - -	66
"Oxygen absorbed" *at once* - - - - - - - -	82
„ „ *in 4 hours* - - - - - - - - -	84
Solids in Suspension - - - - - - - - - -	75
Mineral matter in those Solids - - - - - - - -	57
Solids by Centrifuge (vols.) - - - - - - - -	51

Unsettled Effluents. Hourly Samples. Series B.—Nos. 798, 802 and 805. Drawn April 10th—13th, 1905. It will be remembered that these effluents represent fairly well the dry-weather flow.

The following figures were obtained:—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(0·55 to 0·95)	0·78	(3)
Albuminoid Nitrogen	(0·15 to 0·26)	0·22	(3)
Total Organic Nitrogen	(0·83 to 1·19)	0·96	(3)
Oxidized Nitrogen	(3·24 to 4·15)	3·60	(3)
Total Nitrogen	(4·90 to 5·89)	5·37	(3)
"Oxygen absorbed" at 27°C. (80° F.) *at once*	(0·56 to 0·96)	0·74	(3)
" " " " *in 4 hours*	(2·46 to 3·28)	2·92	(3)
Dissolved Oxygen taken up in 24 hours at 18°C.	(0·22 to 1·21)	0·74	(3)
Incubator Test (Scudder)		2 passed 1 failed	(3)
Incubator Test (by smell)		3 passed	(3)
Smell when drawn		3 good	(3)
Smell when analysed		3 good	(3)
Chlorine	(10·10 to 11·16)	10·55	(3)
Solids in suspension*	(11·4 and 8·8)	—	(2)
Containing Mineral Matter	(7·0 and 3·7)	—	(2)
Solids by Centrifuge (vols.)	(49·0 to 62·5)	54·0	(3)
Ratio of Solids in suspension to Centrifuge solids	(1 to 5·5 and 1 : 5·7)	—	(2)
c.c. per litre. Oxygen in solution when analysed	(6·3)	—	(1)

As was to be expected, because of the more even sewage flow at the time, the hourly effluents of Series B. were very much more uniform in composition than those of Series A., and they were also distinctly better in quality. In appearance they were bright and clear, and of a brownish tint, with brown-coloured solids. They all had a clean smell both when drawn and when analysed, and all readily withstood incubation; they contained, however, on the average, a larger quantity of suspended matter (approximately 9 to 10 parts) than the effluents of Series A., but on the other hand the figure for the absorption of dissolved oxygen in 24 hours was much smaller (0·74), and that for "Oxygen absorbed" from permanganate also smaller. The ammoniacal nitrogen was only 0·78 part, while the oxidized nitrogen amounted to 3·60.

These approximately dry-weather flow effluents may therefore be characterised as well purified and of good quality, apart, of course, from the question of suspended solids, which require to be settled out.

If we again compare the figures for suspended solids and mineral matter in the samples of settled sewage, Nos. 803 and 806, with the corresponding figures in the effluents, Nos. 802 and 805, we find during these two days as much mineral matter leaving the filter as passing on to it; but, as already stated, no conclusive deductions can be drawn from one or two such observations. (The figures for mineral matter are given in brackets.)

———	Suspended Solids and Mineral Matter in :—	
	Settled Sewage.	Effluent.
2nd day	24·7 (6·3)	11·4 (7·0)
3rd day	26·0 (4·8)	8·8 (3·7)
Totals	50·7 (11·1)	20·2 (10·7)

* The figure found for No. 798 appears, on internal evidence, to be questionable, so it is not given here.

Compared with the samples of settled sewage of Series B., the effluents of Series B show the following reduction in figures :—

Calculated on :—	Reduction.
Total Nitrogen	48 per cent.
Ammoniacal Nitrogen	90 „
Albuminoid Nitrogen	81 „
Total Organic Nitrogen	69 „
"Oxygen absorbed" *at once*	82 „
„ „ *in 4 hours*	84 „
Solids in suspension	60 „ (two samples)
Containing mineral matter	4 „ „
Solids by centrifuge (vols.)	61 „

Effluents. Chance Samples. Of the four chance samples of effluent examined, Nos. **3421B**, **681**, **3601** and **3674**, the first three were drawn in dry weather and the last one in wet.

The following results were obtained :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(0·08 to 0·89)	0·57	(4)
Albuminoid Nitrogen	(0·08 to 0·28)	0·18	(4)
Total Organic Nitrogen	(0·28 and 0·58)		(2)
Oxidized Nitrogen	(3·44 to 6·59*)	4·51	(4)
Total Nitrogen	(4·61 to 7·74)	5·75	(3)
Oxygen absorbed at 27°C. (80°F.) *at once*	(0·40 to 0·85)	0·62	(4)
„ „ „ „ *in 4 hours*	(1·23 to 3·80)	2·45	(4)
Dissolved Oxygen taken up in 24 hours at 18°C.	(0·19 to 2·01)	0·92	(4)
Incubator test (Scudder)		3 passed 1 almost passed	(4)
Incubator test (by smell)		†4 passed	(4)
Smell when drawn		4 good	(4)
Smell when analysed		‡4 good	(4)
Chlorine	(8·65 to 12·22)	10·66	(3)
Solids in suspension	(6·3 and 19·8)	—	(2)
Containing Mineral Matter	(2·9 and 11·4)	—	(2)
Solids by Centrifuge (vols.)	(12·3 to 96·0)	39·0	(4)
Ratio of Solids in suspension to Centrifuge solids	(1 : 4·5 and 1 : 4·9)	—	(2)
Oxygen in solution when analysed	*c.c. per litre.* (2·9 and 5·8)	—	(2)

* Probably too low.
† No. 3421B had an unpleasant fishy smell after incubation, but it still had plenty reserve of nitrate.
‡ Assumed in the case of No. 3601.

In general character and appearance these chance samples of effluent resembled the hourly samples already described and, taking them all together, they showed a higher degree of purification than the latter. They all withstood incubation. A few words may be said about them individually:—

No. 3421B, drawn in dry weather in March, 1904, was, relatively speaking, a poor sample but still very well nitrated. Though containing not more than 6 parts of suspended solids, it took up 2 parts of dissolved oxygen in 24 hours, the liquid portion taking up 0·8 part; much nitrite was present after incubation and the incubated liquid had the peculiar unpleasant (but not putrid) odour which usually accompanies this.

No. 681, drawn in dry weather in May 1904, was an effluent of very high class, containing practically all its nitrogen in the oxidized form (6·5 parts nitric nitrogen) and taking up only 0·19 part of dissolved oxygen in 24 hours. Judging from the centrifuge figure, it contained only about 2 parts of suspended solids.

No. 3601, drawn in January, 1905, at 10·50 a.m., was a sample of particular interest, representing as it did an effluent taken after a short period of severe weather, the cold on the preceding evening having been so intense as to freeze the sewage in the tipping troughs. It was a good sample and well oxidized [nitric nitrogen 4·2; suspended solids about 3·0; dissolved oxygen taken up 0·66 (0·32 by the liquid alone)]. This shows either that the frost had not had time to affect the working of the filter or that the filter had recovered itself during the night.

No. 3674, the last effluent examined, was drawn during a period of wet weather in November, 1905, the storm overflow just working at the time. It was one of the less well purified samples and contained as much as 19·8 parts of suspended solids (of which 11·4 were mineral). But again it was well nitrated (3·7 parts nitric nitrogen) and, though it took up 0·81 part of dissolved oxygen in 24 hours, three-fourths of this absorption was due to the suspended matter present.

The following table of figures is interesting as showing the effect of the suspended solids, in six of the effluents examined, upon the figures for absorption of dissolved oxygen from water and from permanganate. In every case the samples were examined (*a*) with the contained solids, and (*b*) after filtration through paper, excepting that Nos. 3604 and 3614 were well settled instead of being filtered.

Number of Sample.	Solids in Suspension.	Solids by Centrifuge (Vols.)	Incubator Test.		Oxygen absorbed from Permanganate at 27° C.		Dissolved Oxygen taken up from Water at 18° C.:—	
			Scudder.	Smell.	*At once.*	*In 4 hours.*	In 24 hours.	In Five Days.
3604 - - - -	5·70	36·0	Passed	Passed	0·77	3·32	2·40	—
3604 - - - - (Settled one hour after taking from basket)	—	1·1	Passed	Passed	0·73	2·88	2·14	—
3611 - - - -	6·60	41·0	Passed	Passed	0·71	2·96	1·58	—
3611 - - - - (Filtered)	—	—	Passed	Passed	0·68	2·12	0·70	—
3614 - - - -	2·70	34·4	Passed	Passed	0·62	2·29	0·93	—
3614 - - - - (Settled for two days)	—	—	Passed	Passed	0·53	2·15	0·68	—
3421B - - -	6·30	2·90	Almost passed	Passed*	0·74	3·17	2·01	—
3421B - - - (Filtered)	—	—	Passed	Passed*	0·66	2·30	0·73	—

* See remarks on No. 3421B, above.

Number of Sample.	Solids in Suspension.	Solids by Centrifuge (Vols.)	Incubator Test.		Oxygen absorbed from Permanganate at 27° C.		Dissolved Oxygen taken up from water at 18° C. :—	
			Scudder.	Smell.	*At once.*	*In 4 hours.*	In 24 hours.	In Five Days.
3601 - - - -	*3·0 (approx.)	17·6	Passed	Passed	0·50	1·61	0·66	—
3601 - - - - (Filtered)	—	—	Passed (practically)	Passed	0·34	1·25	0·32	—
3674 - - - -	19·80	96·0	Passed	Passed	0·85	3·80	0·81	3·60
3674 - - - - (Filtered)	—	—	Passed	Passed	0·60	1·86	0·22	0·73
Average Figures.								
(*a*) Original Effluent	7·4 (approx.)	42·0	All passed	All passed	0·70	2·86	1·40	—
(*b*) Filtered or Settled Effluent	Trace	Trace	All passed	All passed	0·59	2·09	0·80	—

The above figures explain themselves. They show that the suspended solids present in the effluents, while brown coloured (*i.e.*, with the iron present in the more highly oxidized form), are still capable of taking up appreciable quantities of oxygen from water and also from permanganate. In this case the absorption of dissolved oxygen was the more delicate test of the two, the difference in the absorption by the original and filtered samples being 43 per cent., while in the case of the 4 hours' permanganate test it was 27 per cent. The comparative figures for absorption of dissolved oxygen given by the original and the filtered samples of No. 3674 *in 5 days* are worthy of note; this sample contained an exceptionally large quantity of suspended matter, as it was drawn during a period of wet weather.

Bacteriological Notes.—Ten samples were examined bacteriologically. The B. coli test and presumptive tests for B. coli usually yielded positive results with ·001 c.c. to ·0001 c.c. (1000 to 100,000 per c.c.). The results were less satisfactory as judged by the B. enteritidis sporogenes test. It not uncommonly happens that, in the case of percolating filters, the results are better by the B. coli testthan by the B. enteritidis sporogenes test.

Description of the Samples.	Number of B. coli. (or gas-forming coli-like microbes).	B.S. = Bile-salt glucose peptone test. N.R. = Neutral red broth test. In = Indol test. L.P.M. = Lactose peptone milk test.	B. enteritidis sporogenes test.	Remarks.
3421B. Little Drayton filter effluent, 8/3/04.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R.	10 not 100	
681. Little Drayton filter effluent, 5/5/04.	1,000 not 10,000 (− indol) (− clot)	1,000 not 10,000 N.R.	10 not 100	
3601. Little Drayton filter effluent, 17/11/05.	1,000 not 10,000 (+ indol) (+ clot)	1,000 not 10,000 B.S. 10,000 not 100,000 N.R.	100 not 1,000	
3604. Little Drayton filter effluent, 24/1/05.	10,000 not 100,000 (+ indol) (− clot)	10,000 not 100,000 B.S. 10,000 not 100,000 N.R.	100 not 1,000	

* Calculated from the centrifuge figure

Description of the Samples.	Number of B coli (or gas-forming coli-like microbes).	B-S. = Bile-salt glucose peptone test. N.R. = Neutral red broth test. In. = Indol test. L.P.M. = Lactose peptone milk test.	B. enteritidis sporogenes test.	Remarks.
3607. Little Drayton filter effluent, 25/1/05.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 B.S. 10,000 not 100,000 N.R.	100 not 1,000	
3611. Little Drayton filter effluent, 26/1/05.	—	1,000 not 10,000 B.S. 100,000 N.R.	1,000 not 10,000	
3614. Little Drayton filter effluent, 27/1/05.	1,000 not 10,000 (+ indol) (+ clot)	1,000 not 10,000 B.S. 1,000 not 10,000 N.R.	100 not 1,000	
798. Little Drayton filter effluent, 11/4/05.	—	1,000 not 10,000 B.S. 1,000 not 10,000 N.R.	10 not 100	
802. Little Drayton filter effluent, 12/4/05.	—	1,000 not 10,000 B.S. 10,000 not 100,000 N.R.	100 not 1,000	
805. Little Drayton filter effluent, 13/4/05.	—	10,000 not 100,000 B.S. 1,000 not 10,000 N.R.	10 not 100	

Effect of Temperature upon the Working of the Filter.—The observations upon temperature at Little Drayton included a series of measurements taken every few hours over a period of four days, together with isolated measurements made on the occasion of each visit to the works. The lowest effluent temperature noted was 4·5°C. (40·1°F.).

We were fortunate enough to witness the effect of a short spell of very severe weather at Little Drayton. Following some ordinary cold frosty weather, there came on the evening of January 16th, 1905, a sudden blizzard and, although the temperature at the time was not extremely low (−6·0°C. or 21·2°F.), its effect, when accompanied by the high wind, was unexpectedly marked. Notwithstanding the thatched building which encloses the filter, the distributing troughs were practically all frozen up within a quarter of an hour and the temperature of the effluent went down to 4·5°C. (40·1°F.). Probably, if the blizzard had continued, the effect upon the effluent would have been serious; but it only lasted for about an hour, and the troughs then quickly thawed again and recommenced working.

We have concluded from our observations that the ordinary variations of atmospheric temperature have but little influence upon the working of the filter, and that only very exceptional cold would have a serious effect. It may be added, that, as the filter is enclosed in a building, it would be a simple matter to warm it artificially, if necessary.

SUMMARY.

The dry-weather crude sewage at Little Drayton is very strong organically and also bacteriologically, though it contains only a moderate quantity of suspended solids. In times of storm, however, the suspended solids may rise to a very high figure, the increase being due partly to the washing out of the sewers and partly to mineral and other matter brought down by road water. The main reason for the strength of the sewage, notwithstanding that some subsoil water gains access to the sewers, is the small consumption of water per head of population, in a district consisting for the most part of small houses. The whole of the sewage and storm water, up to three times the dry-weather flow, is treated by the installation at the works.

The grit-tanks are well arranged and easily emptied, but they are so small as to effect only a very partial settlement of the grit, etc., from the crude sewage. The

average figures for suspended solids in the two series of hourly samples of the crude and settled sewage were:—

	Crude Sewage.	Settled Sewage.
Series A (wet weather) - - - -	52·7	30·2
Series B (dry weather) - - - -	34·2	19·9

Large quantities of suspended matter, including grit, therefore pass on to the filter, and although much of this escapes with the effluent, more goes on than comes out. As it cannot all be digested in the filter, the filter must eventually become clogged. We think it likely that, in three to four years from the time when the filter came into operation, it will be found necessary to wash or renew the upper half of the filtering material. The local authorities, we understand, do not anticipate that such washing will be attended by any serious difficulty or expense; should this surmise prove to be correct, then it is probably better and more economical to work the filter on the present system, and to have only a very little sludge from the grit chambers to deal with, than to institute larger settling tanks with correspondingly more sludge.

At the present time the method of dealing with the grit-chamber sludge cannot be considered satisfactory, the sludge lagoons being too small and without proper drains. As, however, there is plenty of land available, no difficulty ought to be found in remedying this at small expense.

The settled sewage contains about 40 per cent. less of suspended solids than the crude, but for a settled sewage it is exceedingly strong. The dry-weather hourly samples showed about 20 parts per 100,000 of suspended (including 5·6 parts of mineral) matter passing on to the filter.

One of the features in the construction of the Ducat filter consists in the short porous pipes of which the walls are built and the longer pipes which pass through the whole breadth of the filter.

The quality and size of the filtering material and the depth of the filter are points of great interest. The small granite chippings which constitute the filtering medium are neither porous nor vesicular, and they are evidently of a lasting character. If the pieces of granite were larger, or if the filter were a shallow one, the strong sewage would no doubt pass through too rapidly for adequate purification. Theoretically, therefore, a filter built of material of this nature should be rather deep, and the fragments of which it is composed should be rather small, although, on the other hand, this fineness of material induces a tendency to clog. These are the conditions actually found at Little Drayton.

The distribution of the sewage effected by the tipping troughs is, on the whole, good, but the troughs require daily attention, some five or six out of the sixty-four in use being generally found out of order daily: still, they are quickly put right again. For small volumes of sewage this method of distribution has distinct advantages, in that the tipping of a trough is not dependent upon any particular rate of flow, the length of the period of time between two successive tippings being the only variant. An influx of storm water, therefore, introduces no difficulties here. Further, it is very unlikely that many of the troughs would get out of order at the same time, and hence the distribution as a whole must remain very consistent.

The filter treats up to three times the dry-weather flow of sewage, any excess being diverted on to the sloping side of a grass field by the storm overflow situated at the works. Taking as a basis the gauge measurements made for the Commission between January 13th and March 29th, 1905, the filter treats on the average 48·5 gallons of roughly settled sewage per square yard, or 19·5 gallons per cube yard, per 24 hours. Although the actual volume treated is thus small, it must be borne in mind, on the other hand, that the sewage is a very concentrated one and that the settled sewage still contains much suspended matter.

The effluents examined, apart from the suspended matter which they contained, were for the most part well purified both chemically and bacteriologically. They were invariably well nitrated and showed a good percentage reduction in the figures of analysis, when compared with the settled sewages. In no case has a putrefactive effluent been obtained. At the same time the liquid portion of the effluent, though highly nitrated, was still in some cases capable of taking up appreciable quantities

of dissolved oxygen. The effect of the suspended solids in the effluent is clearly shown by the figures for the absorption of dissolved oxygen in **24** hours by six of the effluents (a) *with* and (b) *without* those solids, the average of the figures being (a) **1·40** and (b) **0·80** parts of oxygen taken up per **100,000** of effluent.

That the effluents require settlement of their suspended solids is further borne out by some observations made upon the small stream or ditch into which the effluent flows. Although on no occasion have any objectionable growths been noticed in this little water-course, and the liquid has always been clear and clean looking along the whole distance of 1½ miles until the river Tern is reached, some of the mud at the bottom of the ditch was seen to be black and putrefactive when it was stirred up. The constant flow of well diluted and well nitrated effluent prevents this being noticeable unless the mud is actually taken up and examined. It should be added, however, that it is occasionally necessary to scoop out the settled matter which accumulates in the ditch at the point of the effluent outfall.

No nuisance from smell has ever been observed at the Little Drayton works excepting during the short time that the detritus tanks are being sludged, and even then it is only slight. Indeed, on the whole, the works are unusually free from smell. Another point that is worthy of being borne in mind is that the general appearance of the works, with the filter enclosed in a nicely thatched building, is in no way suggestive of sewage disposal. These two features of the Ducat process might in some cases constitute strong arguments in its favour.

We should like, in conclusion, to express our thanks to Mr. G. A. Craig, the Surveyor of the Drayton Rural District Council, and to Mr. George Holland, the Manager of the Sewage Works, for help given to us in connection with our work at Little Drayton.

MAIDSTONE SEWAGE WORKS.

(Corporation of Maidstone).

1. Situation of works - - - - -	About $1\frac{1}{2}$ miles from the centre of the Town.
2. Method of treatment - - - - -	(1) Chemical precipitation and continuous flow subsidence; (2) Crude sewage on double contact beds.
3. Population draining to works (in 1903) - -	34,000.
4. Water supply per head and whence obtained -	16·5 gallons. From two sources: the lower green sand and the chalk—a fairly hard water.
5. Number of W.C's - - - - - -	6,900
6. Sewerage system - - - - - -	Partially separate.
7. Average dry weather flow of sewage in gallons per 24 hours (1903) - - - - -	1,500,000.
8. Gallons of sewage per head per day - -	44·1
9. Character of the sewage - - - - -	A domestic sewage containing large quantities of brewery and tannery waste, and some strongly alkaline waste from a paper mill.
10. Period of observations - - - - -	November, 1902, to October, 1903
11. Age of contact beds - - - - -	Four years.
12. Amount of storm water treated on filters during observations - - - - - -	None treated specially; the filters treat a constant quantity of sewage.
13. Total capacity of tanks in gallons - - -	200,000 (roughly).
14. Total area of beds in yards super - - -	395
15. Total cubic content of beds in yards cube -	504·5
16. Nature of filtering medium - - - -	Clinkers:—primary bed, everything above $\frac{3}{4}$ inch; secondary bed, everything under $\frac{1}{2}$ inch, excepting dust.
17. Gallons of settled sewage treated per yard super. per 24 hours (both beds included) - -	30
18. Gallons of settled sewage treated per yard cube per 24 hours (both filters included) - -	23·7
19. Final effluent is discharged into - - -	The river Medway.

FLOW OF SEWAGE.

The greater part of the rain falling upon the roofs of the houses finds its way quickly into the sewers, and comparatively small amounts of rain affect the general flow of sewage. As a rule, however, the volume of sewage is only greatly affected during the time that the rain is falling, and the flow diminishes rapidly when

the rain ceases. Storm water thus brought to the works is usually of a very foul character, especially if the rain occurs after a long period of dry weather, when the putrefying solids from the house gutters and the sewers are flushed down to the works.

The estimated maximum flow which the sewer will carry is between eight and nine million gallons per 24 hours, and as it has been seen running full on several occasions, it is fair to suppose that something like that rate of flow is reached at times, for short periods. We have, however, made no actual gaugings of storm flows at Maidstone.

There are five storm-overflows on the system. They are set so as to come into operation when the flow reaches five or six times the dry weather flow.

Owing to the fact that the small contact beds, whose study was the main object of the observations at Maidstone, receive only a small and constant quantity of sewage, it has not been necessary to make elaborate gaugings of the total flow of sewage. It was necessasy, however, in order to ascertain the character of the sewage, to take average samples of it, and the gauge, to record the total flow, had therefore to be put down. On these gaugings, the dry weather flow at Maidstone during 1903 has been estimated at approximately 1,500,000 gallons per day. Except for a slight rainfall on one of the days, the week in which the measurements were made was a dry one, and was preceded by dry weather; but the summer of 1903 was unusually wet, and the probability is that the measurements recorded are therefore somewhat high.

Another circumstance which militated against accuracy in the measurements was that the weir was flooded for short periods by the tide twice a day.

The general flow of sewage was in the proportion of four volumes in the daytime to one at night. The highest day's flow of the week occurred on the Monday, Tuesday and Wednesday, and the lowest flow, which was considerably less than the flows on the other days, occurred on the Sunday.

Subsoil Water.—During the early morning of most of the days in the dry week mentioned above, the flow of sewage was at the rate of about 450,000 gallons per 24 hours. This is evidence of the presence of a considerable quantity of subsoil water.

Crude Sewage.—Six samples in all were examined, including three sets of hourly samples, Nos. 3,249, 3,253 and 3,256, drawn in September, 1903. No rain fell when the first and last of these were being taken, but during the sampling of the middle one, No. 3,253, there was a rainfall of 0·30 inch on *dry* ground; the flow for that day was therefore somewhat swollen with roof water. The average figures will thus probably indicate a *slightly* more dilute sewage than the reality. Alongside are placed the figures of analysis of a sample of weak night sewage, No. 3,052, drawn on September 23rd, 1903, at 5 a.m., *i.e.* on the day succeeding that on which the 0·30 inch of rain fell. The following results were obtained:—

	Parts per 100,000.	Average.	Number of Estimations.	No. 3252. Weak Night Sewage.
Ammoniacal Nitrogen	(2·94 to 4·04)	3·51	(3)	0·58
Albuminoid Nitrogen	(1·41 to 1·69)	1·52	(3)	0·38
Total Organic Nitrogen	(2·11 to 3·04)	2·62	(3)	0·42
Oxidized Nitrogen		0·0	(3)	0·0
Total Nitrogen	(5·67 to 6·76)	6·14	(3)	1·00
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(3·38 to 5·07)	4·46	(3)	0·54
,, ,, ,, ,, *in 4 hours*	(17·14 to 25·25)	21·03	(3)	3·56
Chlorine	(7·22 to 8·16)	7·74	(3)	
Solids in Suspension	(23·1 to 44·5)	34·80	(3)	6·0
Solids by Centrifuge (vols.)	(215 to 307)	275·0	(3)	
Ratio of Solids in Suspension to Centrifuge Solids	(1 : 6·8 to 1 : 9·3)	1 : 8·1	(3)	

All these sets of samples contained tannery waste, and at least two of them brewery waste, the latter preponderating in the third day's sample, No. 3,256. The suspended solids were coarse, in dark brown lumps, and included hairs, skin, etc., while all the samples had a very unpleasant smell. The average figures of analysis show the Maidstone crude sewage to be very strong as regards organic matter, though not specially strong in an ammoniacal sense. The presence of so much brewery waste must tend to make the sewage a difficult one to purify, and one joint effect of the tannery and brewery wastes is to give rise to a liquid which rapidly acquires a most offensive odour.

The sample of weak night sewage was only about one-sixth as strong as the average samples.

The figures of analysis of the other two chance samples of sewage examined may also be given in detail, as further illustrating what has just been said about the nature of the sewage; the second sample contained a large quantity of yeast cells:—

Parts per 100,000.	No. 3061. Crude Sewage from inlet well, drawn Monday, Nov. 24th, 1902, 3 p.m.	No. 471. Crude Sewage, containing brewery and tan refuse, drawn Tuesday, January 27th, 1903, 2.30 p.m.
Ammoniacal Nitrogen	8·74	—
Albuminoid Nitrogen	2·51	—
Total Organic Nitrogen	4·79	—
Total Nitrogen	13·53	13·35
"Oxygen absorbed" at 27° C. (80° F.) *at once*	6·64	6·23
" " " " *in 4 hours*	34·38	24·32
Chlorine	13·60	10·60
Solids by Centrifuge (vols.)	—	720·0
"Cellulose"	—	21·44

Bacteriological Notes.—Three samples of Maidstone crude sewage were examined bacteriologically. They all yielded positive results with ·00001 c.c. (100,000 per c.c.) with the B. coli, neutral red broth, indol, lactose peptone milk and bile-salt glucose peptone tests. One sample contained 100 and the other two samples 1,000 spores of B. enteritidis sporogenes per c.c

Description of Sample.	B. Coli test.	N.R. = Neutral red broth test. In. = Indol test. L.P.M. = Lactose peptone milk test. B.S. = Bile-salt glucose peptone test.	B. Enteritidis. sporogenes test.	Remarks.
3061. Maidstone Crude Sewage, 24/11/02	100,000 (+indol) (+clot)	N.R. = 100,000 In. = 100,000 L.P.M. = 100,000 B.S. = 100,000	1,000 not 10,000	"Gas" test +·001 c.c. 24 hours at 20°C.
471. Maidstone Crude Sewage, 27/1/03	100,000 (+indol) (+clot)	N.R. = 100,000 In. = 100,000 L.P.M. = 100,000 B.S. = 100,000	1,000 not 10,000	"Gas" test +·001 c.c. 24 hours at 20°C.
3252. Maidstone Crude Sewage, 23/9/03	—	N.R. = 100,000	100 not 1,000	

GENERAL PROCESS.

Screens and Detritus Tanks.—As it flows into the works, the sewage passes two half-inch screens. These remove, as a rule, large suspended matter amounting to about nine barrow loads a day. Sometimes the quantity amounts to twice as much. The screenings are given away free to farmers.

Grit Chambers.—The sewage passes through grit chambers before entering either of the precipitation tanks. They are of different sizes, however, the grit chamber at the entrance of No. 1 tank being a small one, while that at the entrance of No. 2 tank is larger, and holds about 2,700 gallons. Both are cleaned out every other week.

PRECIPITATION TANKS.

Number - - - - - -	2.
Size of each - - - - -	No. 1 tank, (roughly) 153 feet by 27 feet 9 inches (at the top), with an average depth of 4 feet 4 inches. No. 2 tank, (roughly) 157 feet by 28 feet 6 inches (at the top), with an average depth of 4 feet 5 inches.
Capacity of each tank - - -	Roughly, 100,000 gallons.
Total capacity - - - - -	Roughly, 200,000 gallons.

Construction.—Brick and cement tanks, No. 1 containing three submerged walls at intervals, and No. 2 containing no walls. The bottom of No. 1 tank is flat, and the side walls meet it at a curve; but in No. 2 tank, which was originally constructed in the same way as No. 1, the side walls are now brought in to such an extent, one in a straight line and the other with a configuration like the letter "S," that they almost meet. The reason for this alteration was because of leakage from the river or from springs.

The Precipitant.—Lime is the precipitant used. It is ground with water and added as milk of lime. The amount added is equivalent, on a flow of one and a half million gallons per day, to about 5 grains per gallon.

Flow Through.—With a dry weather flow of 1,500,000 gallons per day, the flow through the tank would be once in 1·6 hours, at the rate of 19·3 inches per minute.

Working.—The tanks are used separately. In the case of No. 1, the sewage enters the tank over a long horse-shoe sill extending right across the tank, and in doing so it also passes a half-inch screen. In No. 2 tank the sewage flows from the grit chamber over a wall, which acts as a sill while the tank is filling, but becomes a submerged wall when the tank is full. The tank liquor issues from the tank in both cases over a long sill protected by a scum board, and then flows direct to the tidal waters of the river Medway, about two miles further down towards the sea.

Sludging.—Each of the tanks is cleaned out every other week by pumping the sludge, after the supernatant liquid has been run off, either direct to the sludge presses or to a lagoon.

The sludge in No. 1 tank is pushed into a sludge sump for this purpose; but in No. 2 tank, owing to the fact that the shape of the bottom of the tank makes it impossible for men to enter and assist the flow of sludge with squeegees, it has been found necessary to bring a suction pipe of the pump into the tank and carry it a considerable way along its length. This pipe previously withdrew sludge from three small sumps, placed at intervals, but it now only withdraws sludge from one sump near the inlet end, and a consequence is that the tank is never properly emptied. The importance of this will be readily seen when it is stated that it results in the remaining sludge becoming septic; the evolution of gas which is continually taking place in this tank, during wet weather especially, has the effect of undoing some of the settlement of suspended matter.

Both the pressed cake and the air-dried sludge are tipped together on the works. Farmers are paid sixpence a ton for taking away the cake and sludge including loading and unloading in the barges.

Considerable nuisance arises from the tanks in the ordinary working, and it is much accentuated when the sludge is being removed from them.

Precipitation Liquor.—Three sets of hourly samples and three chance samples were examined chemically. The hourly samples, Nos. 3250, 3254 and 3257, drawn in September, 1903, under the same conditions as the hourly samples of crude sewage, gave the following figures on analysis :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(3·17 to 4·05)	3·53	(3)
Albuminoid Nitrogen	(0·91 to 1·04)	0·99	(3)
Total Organic Nitrogen	(1·64 and 1·64)	1·64	(2)
Oxidized Nitrogen	-	0·0	(3)
Total Nitrogen	(5·69 and 5·02	5·36	(3)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(2·12 to 2·69)	2·43	(3)
" " " " " *in 4 hours*	(9·34 to 11·40)	10·71	(3)
Chlorine	(6·44 to 8·38)	7·51	(3)
Solids in suspension	(12·3 to 15·8)	14·0	(3)
Solids by Centrifuge (*vols.*)	(77·0 to 90·0)	84·0	(3)
Ratio of solids in suspension to Centrifuge solids	(1 : 5·3 to 1 : 7·3)	1 : 6·1	(3)

These figures show that the average precipitation liquor at Maidstone is very strong. Like the sewage, it has an unpleasant smell, though the smell is less pronounced. The settlement after precipitation is not a good one, 14 parts of suspended solids being left in the liquor.

It will be seen that the figures for ammoniacal nitrogen in the hourly sets of crude sewage and of precipitation liquor are almost identical, viz., 3·51 and 3·53, and the same with the figures for chlorine :—7·74 and 7·51. The two sets are therefore strictly comparable. The precipitation liquor shows the following reduction figures on the sewage :—

Calculated on the albuminoid nitrogen	35 per cent. reduction.
Calculated on the total organic nitrogen*	32 " " "
Calculated on "oxygen absorbed" at once	46 " " "
Calculated on "oxygen absorbed" in 4 hours	49 " " "
Calculated on suspended solids	60 " " "
Calculated on centrifuge solids	69 " " "

The figures of analysis of the three chance samples of precipitation liquor may also be given separately here. It will be seen that the first of these, No. 472, was abnormally strong, from the presence in it of brewery refuse, with an excessive amount of suspended solids, although the turbid liquid did not *appear* to contain a great deal; in other words, the solids were very light and difficult to settle. No. 3195 was also very strong

* Two samples in each case.

for a precipitation liquor and contained also far too much suspended solid. No. 3233 was of about the same strength as the average samples.

Parts per 100,000.	No. 472. Drawn Tuesday, January 27th, 1903, 3.45 p.m.	No. 3195. Monday, July 20th, 1903, 11·25 a.m.	No. 3233. Thursday, August 27th, 1903, 2·30 p.m.
Ammoniacal Nitrogen	6·77	—	—
Albuminoid Nitrogen	1·97	—	—
Total Organic Nitrogen	4·61	—	—
Total Nitrogen	11·38	—	6·76
"Oxygen absorbed" at 27° C. (80° F.) *at once*	12·42	4·95	2·87
" " " " " *in 4 hours*	38·16	16·27	11·31
Chlorine	11·06	—	—
Solids in suspension	46·9	24·8	13·8
Solids by centrifuge (vols.)	282·0	126·0	91·0
Ratio of solids in suspension to centrifuge solids	1 : 6·0	1 : 5·1	1 : 6·6
"Cellulose"	7·87	—	—

Bacteriological Notes.—Three samples of precipitation liquor were examined bacteriologically. The B. coli test and presumptive tests for B. coli (neutral red broth, indol, lactose peptone milk and bile salt glucose peptone tests) yielded positive results with ·00001 c.c. (100,000 per c.c.) All three samples contained 1,000 spores of B. enteritidis sporogenes per c.c. Sample 472 contained 2,800,000 microbes per c.c. (agar at 37° C).

Description of Sample.	B. coli test.	N.R. = Neutral red broth test. In. = Indol test. L.P.M. = Lactose peptone milk test. B.S. = Bile-salt glucose peptone test.	B. Enteritidis sporogenes test.	Remarks.
472 Maidstone Precipitation liquor, 27/1/03	100,000 (+indol) (+clot)	N.R. = 100,000 In. = 100,000 L.M.P. = 100,000 B.S. = 100,000	1,000 not 10,000	"Gas" test +·001 c.c. 24 hours at 20° C., 2,800,000 microbes per c.c. (agar at 37°C.)
3195 Maidstone Precipitation liquor, 20/7/03	—	N.R. = 100,000	1,000 not 10,000	
3233 Maidstone Precipitation liquor, 27/8/03	100,000 (– indol) (+clot)	N.R. = 100,000	1,000 not 10,000	

EXPERIMENTAL DOUBLE CONTACT BED PROCESS.

Intake.—The sewage used for treatment upon the contact beds is taken direct from the sewers without passing through the screening chamber. A four inch pipe, brought into the main sewer at an angle, carries the sewage to a small sump about four feet square. Here it passes a half-inch screen, and is then pumped by a four inch centrifugal pump to the contact beds, passing on its way a second screen of a quarter-inch mesh. Very little suspended matter appears to be removed by either of these screens, owing to the fact that the flow, when the beds are being filled, is a rapid one. Practically speaking, therefore, crude sewage is treated on the beds.

PRIMARY BED.

Number - - - - -	1. (Note :—There are in reality two beds; one bed, however, which was constructed rather later than the other, has ordinary earth walls on three of its sides. In 1901 it began to leak so badly that it could not be filled, and as the leakage has not been remedied, it has not been included in our observations).
Size of bed - - -	45 feet by 39 feet 4 inches.
Area - - -	196·6 square yards.
Cubic content - - -	218·44 cube yards.
Depth of Material - - -	3 feet 4 inches.
Material- - - - -	Furnace clinker consisting of all sizes above $\frac{3}{4}$ inch diameter.
Construction - - - -	Cement and concrete throughout.
Distribution - - - -	None.
Underdraining- - - -	5 rows of three-inch agricultural pipes, radiating from an outlet chamber.
Age - - - - - -	The bed was started in October, 1898.

Working.—During the four years from October, 1898, when it was first brought into use, to the commencement of the observations in 1902, No. 1 primary bed received on an average 2·3 fillings per week. The rate of working, however, was not uniform, being 5 fillings per week from October, 1898, to November, 1899, and only 1·5 fillings per week from November, 1899, to the commencement of the observations in November, 1902, the latter rate of working being adopted for the purpose of keeping the bed matured. During the observations for the Commission, it was given only one filling a day, this rate being chosen in order that it should have the best possible chance of being effective.

The time in which the bed could be filled has also varied. With the new bed it was about 1½ hours, but during the observations it was usually about one hour. The contact given in the bed during the observations was 1½ hours.

Capacity.—The original empty tank capacity of No. 1 primary bed was 36,860 gallons, and, assuming that half the water space of the tank was occupied by the clinker when first put in, the original water capacity was therefore 18,430 gallons.

On November 18th, 1903, at the end of the observations, the water capacity of this bed was measured, and it was found to be 11,700 gallons. After having been used, therefore, at a slow rate of working for rather more than five years, the bed still retained 31·7 per cent of the original empty tank capacity, and 63·4 per cent of the original water capacity.

This measurement was the only one made, but it is sufficient to show that at this slow rate of working the loss of capacity has not been great. It is the more interesting in that it shows that a contact bed can, under some conditions, still retain a considerable proportion of its water capacity, even although it contains a large quantity of accumulated matter from the sewage. At the time the measurement was made, there was undoubtedly a very large quantity of spongy earthy matter amongst the material, and the level of the material was so much raised by this as to be in some places above the level of the retaining walls. The probable explanation is that the small number of fillings given to the bed have allowed it ample time to drain, and thus to permit the more resistent organic matter of the sewage to

become changed into a permeable humus-like material. Instead of causing a serious loss in capacity, therefore, by retaining water and becoming swollen and sodden, the earthy matter has acted as a filtering medium.

Clinker from Primary Bed.—On November 19th, 1903, two samples of clinker, A and B, were drawn from the primary bed No. 1, A being taken at a depth of 6 inches to 9 inches, so as to represent the upper portion of the bed, while B was taken at a depth of 3 feet to 3 feet 6 inches from the surface, so as to represent the lower portion. A was a mixture of five and B a mixture of two samples, and the two together were fairly representative of the bed as a whole. A contained many worms and much jelly-like substance, together with hair, fragments of leaves, etc. B also contained a good many worms and a fair amount of gelatinous matter. The bed had last been filled two days before, on November 17th.

After careful sub-sampling, convenient quantities (equal to about 500 grms. of the dry material in each case) were elutriated with distilled water through a fine zinc sieve with holes of 0·25 m.m. diameter, the soft lumps being broken down with the finger or with a rubber-tipped glass rod. In this way the following fractions were obtained, the figures representing percentages of the *nearly* dry weight * ; fractions (*a*) and (*b*) were separated fairly well by hand.

	A	B
(*a*) Large pieces {12 m.m. to 50 m.m. in A; 7 m.m. to 80 m.m. in B}	65·6 per cent.	84·0 per cent.
(*b*) Small pieces {Coarse sand up to 18 m.m. in A; Coarse sand up to 13 m.m. in B}	12·9 ,,	6·9 ,,
(*c*) Soil, sand and dust that passed through sieve (*i.e.*, particles under 0·25 m.m. diameter)	21·5 ,,	9·2 ,,
(*d*) Colloidal matter	0·03 ,,	0·02 ,,
	100·0 ,,	100·0 ,,

Fractions A (*a*) and B (*a*) were both quite clean.

Fractions A (*b*) contained many particles of leaf, fibre, hair, etc., while B (*b*) was very clean.

The analyses of fractions A (*c*) and B (*c*) are given below.

The colloidal matter of B (*d*) was mainly organic, but it also contained a good deal of iron ; and the same no doubt applied to the colloidal matter of A (*d*).

Analysis of :—	A (*c*)	B (*c*)
Moisture	2·09 per cent.	1·34 per cent.
Volatile matter	38·58 ,,	41·02 ,,
Non Volatile matter	59·33 ,,	57·64 ,,
	100 0 ,,	100·0 ,,
Nitrogen	2·01 per cent.	1·25 per cent.
Matter soluble in Ether	0·70 ,,	—
(*a*) "Cellulose" (by Alkali, Acid and Ether)	9·19 ,,	13·33 ,,
(*b*) "Cellulose" (by Alkali, Acid and Ether, after Acid permanganate)	6·07 ,,	8·31 ,,
Grit from (*a*)	39·82 ,,	40·31 ,,
Grit from (*b*)	36·36 ,,	38·82 ,,

* These figures are only to be taken as approximate.

The upper part of the bed contained 21·5 per cent. of fine residual matter, derived partly from the breaking down of the sewage, and partly from the disintegration of the clinker itself, while the lower portion contained 9·2 per cent.

Broadly speaking, therefore, there was twice as much humus, sand and dust in the upper part of the bed as in the lower, the former being also twice as rich in nitrogen as the latter.

Primary Effluents.—Only four ordinary chance samples, Nos. 3062, 473, 483 and 3196A were examined chemically, the first three being drawn in the cold months of 1902-3, and the fourth in July of 1903. The length of contact was in most cases about $1\frac{1}{2}$ hours.

They gave the following figures :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - - - -	(4·08 and 2·35)		(2)
Albuminoid Nitrogen - - - - - - -	(0·68 and 0·57)		(2)
Total Organic Nitrogen - - - - - - -	(1·21 and 0·91)		(2)
Oxidized Nitrogen - - - - - - -	(0·0 to 0·96)	0·5 approx.	(4)
"Oxygen absorbed" at 27° C. (80° F.) *at once* - -	(1·11 to 2·51)	1·91	(4)
,, ,, ,, ,, *in 4 hours* - -	(2·81 to 8·17)	6·24	(4)
Dissolved oxygen taken up in 24 hours at laboratory temperature - - - - - - -	(More than 1·4 and more than 1·1)		(2)
Incubator Test (Scudder) - - - - - -	1 probably +, 3—		(4)
Incubator Test (by smell) - - - - - -	1 probably +, 3—		(4)
Smell when drawn - - - - - - -	1 +, 2—		(3)
Smell when analysed - - - - - - -	1 probably +, 3—		(4)
Solids by centrifuge (vols.) - - - - - -	(22·0 to 37·0)	28·0	(3)

Three of these primary effluents were noted as having a brewery smell when analysed. Considering the strong nature of the sewage which the bed was called upon to treat, the results are very fair. Though the effluents were far from being fully purified, one of them probably withstood the incubator test, and three of them contained some oxidized nitrogen, though a good deal of this was in the form of nitrite.

The analyses are much too few in number to allow of any rigid comparison between these chance samples of effluent and the hourly samples of the crude sewage which this primary bed was treating. But, roughly speaking, the organic impurity of the sewage, as measured by the 4-hours permanganate test, was reduced by about two-thirds, while the suspended solids, as measured by the centrifuge, were reduced by about nine-tenths.

In addition to the above chance samples, two special samples of *last runnings* from the primary bed, Nos. 494 * and 516, were examined. Both of these were sufficiently purified to stand the incubator test, even although they had no great reserve of nitrate to fall back upon (about 0·4 part nitric nitrogen in each case).

Bacteriological Notes.—Four samples of primary bed effluent were examined bacteriologically. The B. coli test and presumptive tests for B. coli (neutral red broth, indol, lactose peptone milk, and bile-salt glucose peptone tests) usually yielded positive results with ·00001 c.c. (100,000 per c.c.). All the samples contained 100 spores of

* No. 494 was from primary bed No. 2.

B. enteritidis sporogenes per c.c. Sample 473 contained 2,280,000 microbes per c.c. (agar at 37°C.).

Description of Sample.	B. coli test.	N.R.=Neutral red broth test. In.=Indol test. L.P.M.=Lactose peptone milk test. B.S. = Bile-salt glucose peptone test.	B. Enteritidis sporogenes test.	Remarks.
3062 Maidstone primary bed effluent, 24/11/02	10,000 not 100,000 (+indol) (+clot)	N.R.=100,000 In.=10,000 not 100,000 L.P.M.=100,000 B.S.=100,000	100 not 1,000	"Gas" test+·01c.c. 24 hours at 20°C.
473 Maidstone primary bed effluent, 27/1/03	100,000 (+indol) (+clot)	N.R =100,000 In.=10,000 not 100,000 L.P.M.=100,000 B.S.=100,000	100 not 1,000	"Gas" test+·01c.c. 24 hours at 20°C. 2,280,000 microbes per c.c. (agar at 37°C.
483 Maidstone primary bed effluent, 24/2/03	100,000 (+indol) (+clot)	N.R.=100,000 In.=100,000 L P.M =100,000 B.S.=100,000	100 not 1,000	
3196A Maidstone primary bed effluent, 20/7/03	—	N.R.=100,000	100 not 1,000	

SECONDARY BED.

Number - - - - - -	One.
Size - - - - - -	45 feet 4 inches by 39 feet 4 inches.
Area - - - - - -	198·1 square yards.
Depth of material - - - -	4 feet 4 inches.
Cubic content - - - - -	286·1 cubic yards.
Material - - - - - -	Furnace clinker, consisting of everything under ½ inch diameter, but with the dust taken out.
Construction - - - - -	Cement and concrete throughout.
Distribution - - - - -	2 half pipes running from the middle of the upper end of the bed to the opposite corners.
Underdraining - - - -	5 rows of 3-inch agricultural pipes, radiating from an outlet chamber.
Age - - - - - -	The bed was started in October, 1898.

Working.—Like the primary bed No. 1, this bed has treated varying quantities of liquid per day, and at one time when primary bed No. 2 was in use, it took the effluent from that bed also, and was receiving four fillings per day. During these observations, however, it received one filling per day, with a contact of one hour.

Capacity.—No measurements of capacity have been made on the secondary bed, but it may be said that the material in it was so clean at the end of the observations that there can be no possible doubt that it retained at that time a very large percentage of its original water capacity.

Amount of Sewage treated upon the Beds.—Assuming from the capacity gauging made in November, 1903, which gave the primary bed capacity at 11,700 gallons, that the average capacity of this bed for the year (1903) was approximately 12,000 gallons, the rate of filtration in the process, primary and secondary beds together, during the observations, was as follows:—

Per square yard per 24 hours - - - - -	30 gallons.
Per cube yard per 24 hours - - - - -	23·7 gallons.

Secondary Effluents.—In addition to two experimental samples, nine ordinary samples of secondary effluents were examined chemically; the numbers being 3063,

484, 517, 543, 3,197B, 3,234, 3,248, 3,251 and 3,255. They were drawn at intervals between November 24th, 1902, and September 23rd, 1903, usually in the early afternoon, and most of them in the warm months, the last three—Nos. 3248, 3251, and 3255—being taken on the same days as the hourly samples of sewage and of precipitation liquor. All the samples were drawn at mid-flow, and in nearly every case the weather was dry.

The following figures were obtained :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(0·23 to 1·67)	0·92	(6)
Albuminoid Nitrogen	(0·08 to 0·33)	0·22	(6)
Total Organic Nitrogen	(0·39 and 1·02)		(2)
Oxydized Nitrogen	(0·26 to 2·19)	1·23	(9)
Total Nitrogen	(1·87 to 4·83)	3·20	(3)
"Oxygen absorbed" at 27°C. (80°F.) *at once*	(0·28 to 1·44)	0·72	(9)
,, ,, ,, ,, *in* 4 *hours*	(1·05 to 3·80)	2·52	(9)
Chlorine	(7·34 to 9·30)	8·29	(4)
Incubator test (Scudder)	6+, 2−		(8)
Incubator test (by smell)	5+, 2 (?), 1−		(8)
Smell when drawn	7+, 1−		(8)
Smell when analysed	8+		(8)
Solids in suspension	(Trace to 3·7)	1·31	(5)
Solids by centrifuge (vols.)	(Trace to 30·0)	13·0	(8)
Ratio of solids in suspension to centrifuge solids	1 : 15 and 1 : 26		
c.c. per litre Oxygen in solution		Practically none	(8)

These effluents varied in appearance from slightly opalescent, with practically no suspended solids, to brown and rather turbid, and all of them had an inoffensive smell on the day of analysis, though in a few cases a faint brewery odour still persisted in them. In samples Nos. 3251 and 3255 the suspended solids (2·0 and 0·85 respectively) were determined in portions of the liquid which had stood in partially filled bottles for two to three weeks, *i.e.*, the finely divided solids were allowed to aggregate before being filtered off. It is needless to say that these—very flocculent—solids consisted almost entirely of organic matter. The secondary effluents, therefore, are very free from suspended solids. Six out of the nine samples were well nitrated, but two of those three which were poor in nitrate failed to withstand incubation ; the third sample, which failed to stand the incubator test, contained as much as 2·19 parts of oxydized nitrogen. Practically only one sample out of seven tested contained a little dissolved oxygen on the morning of analysis. The dissolved oxygen taken up in 24 hours was estimated in three cases only, and in one of these approximately, so there are too few data to generalize from. But, taking all the figures of analysis together, these effluents may be classed as moderate. They show quite clearly that two contacts of a strong brewery and tannery sewage, like that at Maidstone, are barely sufficient to produce a thoroughly high class effluent, with one filling of each bed per day.

As compared with the hourly samples of crude sewage, these effluents show the following reduction in figures :—

Calculated on the Albuminoid Nitrogen	85	per cent.	
,, "Oxygen absorbed" *at once*	84	,,	
,, ,, ,, *in* 4 *hours*	88	,,	
,, Solids in suspension	97	,,	approx.
,, Solids by centrifuge (vols.)	95	,,	,,

Unfortunately there are too few determinations of total nitrogen in the effluents to allow any deductions to be drawn as to how much nitrogen has disappeared during the two contacts of the sewage.

A word or two may be said in conclusion with regard to the two experimental samples of secondary effluent, Nos. 494 and 3235.

No. 495 represents the first runnings from the secondary bed, for comparison with No. 494, the last runnings from the primary bed. Both samples withstood incubation, but No. 495 was much better nitrated than the other; on the other hand, it lost more nitrate upon incubation (these nitrate estimations were made by the approximate pyrogallic acid method). The following figures may be given :—

Parts per 100,000.	No. 494.	No. 495.
Nitric Nitrogen	0·40 approx.	1·50 approx.
" after incubation	0·30 "	0·65 "
"Oxygen absorbed" at 27°C. (80°F.) *at once*	0 94 "	0·58 "
" " " " *in 4 hours*	2·11 (5 hours)	1·57 "
Incubator Test (Scudder)	+	+
Incubator Test (by smell)	+	+
Solids by centrifuge (vols.)	14·0	Trace.

No. 3,235 represented the last portion of the flow from the first emptying for the day of Bed No. 1, No. 3,234 (included in the nine ordinary samples which have been discussed) being the average or mid-flow sample from this filling. There was almost no difference in the figures of analysis of the two samples, excepting that the last runnings was slightly more nitrated than the other (1·78 against 1·49).

Bacteriological Notes.—Nine samples of secondary bed effluent were examined bacteriologically. The B. coli test and presumptive tests for B. coli (neutral red broth, indol, lactose peptone milk and bile-salt glucose peptone tests) yielded positive results with from ·0001 to ·00001 c.c. (10,000 to 100,000 per c.c.), usually positive results with ·00001 c.c. (100,000 per c.c.). The B. enteritidis sporogenes test yielded results as follows:—Two samples 1, one sample 10, five samples 100, and one sample 1,000 spores per c.c.

Description of Sample.	B. coli test.	N.R. = Neutral red broth test. In. = Indol test. L.P.M. = Lactose peptone milk test. B.S. = Bile-salt glucose peptone test.	B. Enteritidis sporogenes test.	Remarks.
3063 Maidstone secondary bed effluent 24/11/02	100,000 (+ indol) (+ clot)	N.R. = 100,000 In. = 100,000 L.P.M. = 100,000 B.S. = 100,000	100 not 1,000	"Gas" test + ·01 c.c. 24 hours at 20° C.
484 Maidstone secondary bed effluent 24/2/03	10,000 not 100,000 (+ indol) (+ clot)	N.R. = 10,000 not 100,000 In. = 10,000 not 100,000 L.P.M. = 100,000 B S. = 100,000	100 not 1,000	
495 Maidstone secondary bed effluent 12/3/03	—	N.R. = 10,000 not 100,000	1 not 10	
543 Maidstone secondary bed effluent 3/6/03	—	N.R. = 100,000	100 not 1,000	

Description of Sample.	B. coli test.	N.R. = Neutral red broth test. In. = Indol test. L.P.M. = Lactose peptone milk test. B.S. = Bile-salt glucose peptone test.	B. Enteritidis sporogenes test.	Remarks.
3197B Maidstone secondary bed effluent 20/7/03	—	N.R. = 100,000	10 not 100	
3234 Maidstone secondary bed effluent 27/8/03	100,000 (+ indol) (+ clot)	N.R. = 100,000	1 not 10	
3248 Maidstone secondary bed effluent 21/9/03	10,000 not 100,000 (– indol) (+ clot)	N.R. = 10,000 not 100,000	100 not 1,000	
3251 Maidstone secondary bed effluent 22/9/03	—	N.R. = 100,000	100 not 1,000	
3255 Maidstone secondary bed effluent 23/9/03	—	N.R. = 10,000 not 100,000	At least 1,000	

SUMMARY.

The crude sewage is very strong as regards organic matter, though not specially strong in ammonia, and it has a very pronounced unpleasant smell. From the gaugings made in September, 1903, it was obvious that, in that year at all events, large quantities of subsoil water gained access to the sewers, the water supply only accounting for about 600,000 gallons out of a total flow of 1,500,000 gallons per day. As a rough estimate, based upon the night flow gaugings, its amount, together with leakage from taps, was at this time probably about 500,000 gallons per 24 hours. Of the remaining 400,000 gallons reaching the works during the week in which the measurements were made, it may be broadly inferred that the greater portion consisted of trade refuse, coming mainly from breweries and tanneries which have their own water supply.

The contact beds, both primary and secondary, were constructed in 1898, the primary bed being filled with clinker of all sizes above $\frac{3}{4}$ inch diameter, and the secondary with clinker under $\frac{1}{2}$ inch diameter, but with the dust removed.

During the four years from October, 1898, when primary bed No. 1 was brought into use, to October, 1902, this bed received on an average 2·3 fillings of crude sewage per week, but the rate throughout these four years was not uniform, thus :— in the 13 months from October, 1898, to November, 1899, the rate was 5 fillings per week, while in the 36 months from November, 1899, to November, 1902, it was only 1·5 fillings per week, this latter rate being carried on merely to keep the bed matured. During the year of observation, it received 6 fillings per week (resting on Sundays).

The capacity of the bed was measured in November, 1903, and was found to be 11,700 gallons, *i.e.* it was equal to 31 per cent. of the original empty tank capacity, or 62 per cent. of the original water capacity (on the usual assumption of 50 per cent. water capacity when the bed was newly filled with material). After five years working, therefore, at the above slow rate (a rate of nearly one filling per day for the first and fifth years, and one filling every four or five days for the intermediate three years), the bed was still in good working order.

In the 13 months from October, 1898, to November, 1899, the secondary bed No. 1 received effluent from No. 1 primary bed at the rate of 5 fillings per week, while from November, 1899 to October, 1902, it received effluent from primary beds Nos. 1 and 2 together,* at the rate of 2·8 fillings per week. In these four years, therefore, it

* Secondary bed No. 2 was started in November, 1899.

received, *on an average*, 3·4 fillings per week, and during the subsequent year of observation 6 fillings per week. Although no gaugings of this bed were made, it was quite evident that it remained perfectly clean and in good condition ; this is, however, only what was to be expected, seeing that the primary bed retained something like nine-tenths of the suspended solids of the sewage.

The primary bed, working in its fifth year at the rate of 6 fillings per week, reduced the organic impurity of the sewage—as measured by the 4 hours' "oxygen absorbed" test—by about two-thirds, and the suspended solids by about nine-tenths. For a first process, therefore, it effected a good purification, though the resulting effluent, regarded by itself, was, of course, not sufficiently purified. From the secondary bed an effluent was obtained which may be described as of moderate quality, chemically speaking, but very free from suspended solids. Therefore, for a crude sewage of the organic strength and character of that at Maidstone, two contacts at the rate of six fillings per week in both beds are barely sufficient to produce a satisfactory effluent. Although the sewage has a strong unpleasant smell, there is practically no nuisance caused by its treatment on contact beds under the conditions described.

The main points of importance brought out by these observations are as follows:—

1. That a strong sewage, containing brewery and tannery wastes in large quantity, can be purified on contact beds (almost sufficiently purified by double contact, at the rate of one filling per day on both beds);

2. That loss of capacity is not serious in the primary bed, if a very slow rate of working (not exceeding one filling per day) is adopted, and this, of course, applies in much greater degree to the secondary bed;

3. That although the Maidstone sewage is of such a nature as readily to give rise to nuisance, no nuisance is produced by this treatment on contact beds.

We may call attention to the fact that the addition of about 5 grains of lime, per gallon of sewage, followed by so rapid a flow as once through the tank in six hours, is insufficient to produce a fairly clarified precipitation liquor; the sets of hourly samples examined contained as much as 14 parts of suspended solids per 100,000. The ordinary working of the precipitation tanks gives rise to a distinct nuisance, the smell from them being at times very unpleasant, and this is accentuated when sludge is being removed from the tanks.

We should like, in conclusion, to express our thanks to Mr. T. F. Bunting, Borough Surveyor of Maidstone, and Mr. Doe, Manager of the Sewage Works, for assistance in connection with our work at Maidstone.

NEWTON-LE-WILLOWS CENTRAL SEWAGE WORKS.

(NEWTON-IN-MAKERFIELD URBAN DISTRICT COUNCIL).

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1. Situation of works - - - - - -	About a mile from the most thickly populated area.
2. Method of treatment - - - - - -	Filtration of slightly settled sewage by single contact.
3. Population draining to works during observations	9,000 (estimated avarage).
4. Water supply in gallons per head and whence obtained - - - - - - - -	14 gallons ; from bore holes in the New Red Sandstone—a moderately hard water.
5. Number of W.C.'s - - - - - -	About 30.
6. Sewerage system - - - - - - -	Combined.
7. Average dry weather flow of sewage in gallons per 24 hours - - - - - - - -	210,000
8. Gallons of sewage per head per day - - -	16.
9. Character of the sewage - - - - -	Mainly slopwater sewage.
10. Period of observations - - - - -	March, 1902, to July, 1905.
11. Age of contact beds - - - - - -	2 years.
12. Amount of storm water treated on beds during observations - - - - - - -	Very little.
13. Total capacity of tanks in gallons - - -	No tanks are used.
14. Total area of filters in yards super - - -	657.
15. Total cubic content of filters in yards cube - -	767.
16. Nature of filtering medium - - - -	Hard cinder clinker, broken, gauged and riddled, from ¼″ to 2″ in diameter.
17. Gallons of sewage treated per yard super per 24 hours (all filters included) - - - - -	106 (average).
18. Gallons of sewage treated per yard cube per 24 hours - - - - - - - -	91 (average).
19. The final effluent is discharged into - - -	The Newton Brook, a polluted stream which joins the Sankey Brook, and finally flows into the Irwell at Warrington.

FLOW OF SEWAGE.

The area is sewered on the combined system, and as therefore a considerable portion of the rain water falling upon it finds its way to the sewers, the flow of sewage at times is largely increased. There are three storm overflows on the system, however, and as these are set so as to come into operation when the flow of sewage reaches a volume equal to three times the dry weather flow, a considerable portion of it is diverted either into the Newton Brook direct or into small tributaries.

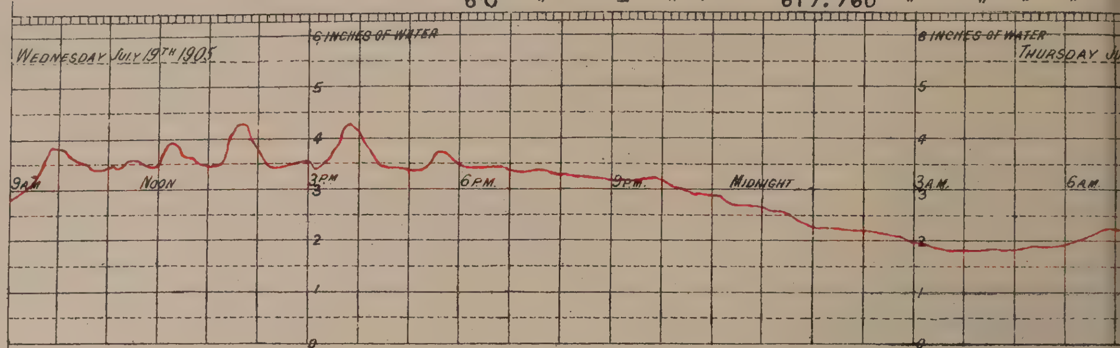
On several occasions flows exceeding 350,000 gallons per day have been measured at the outfall ; but as this was the limit of the gauge, we have no exact records of the flow at

Diagram T.

Diagrams showing flow of Sewage at Newton-le-Willows as falling over a Weir 12" wide.

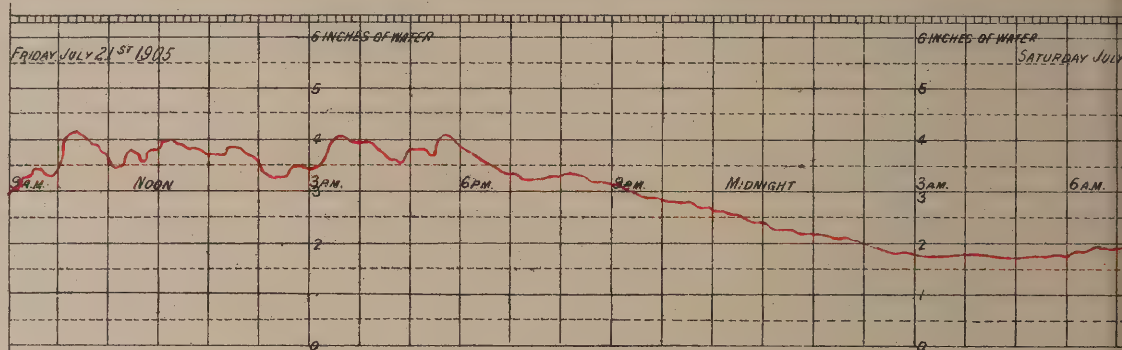
Note:- Over a Weir 12" wide	1·5 inches	=	a rate of	76,896	gallons per 24 hours.
	2·0 "	=	" " "	118,080	" " " "
	3·0 "	=	" " "	217,440	" " " "
	4·0 "	=	" " "	335,520	" " " "
	5·0 "	=	" " "	462,240	" " " "
	6·0 "	=	" " "	617,760	" " " "

Dry day.
Rainfall nil.



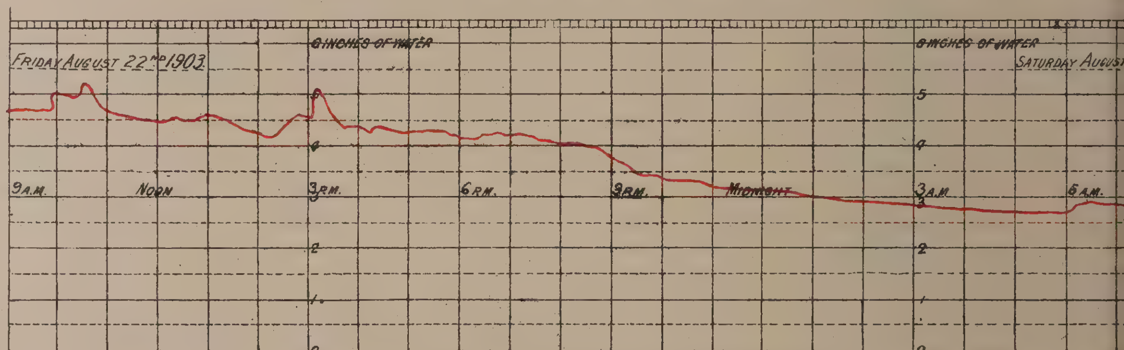
TOTAL FLOW FOR THE 24 HRS. = 212,470 GALLONS

Dry day.
Rainfall nil.



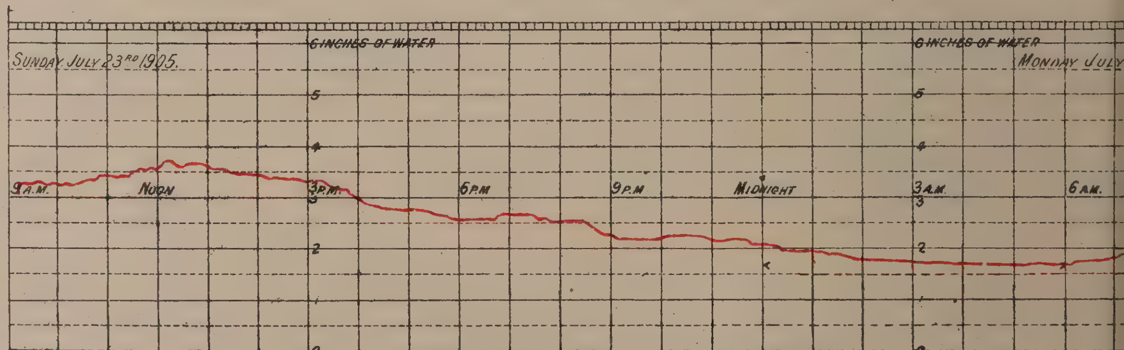
TOTAL FLOW FOR THE 24 HRS. = 202,410 GALLONS

Dry Day.
Rainfall nil.
Following day of heavy rainfall on dry ground.



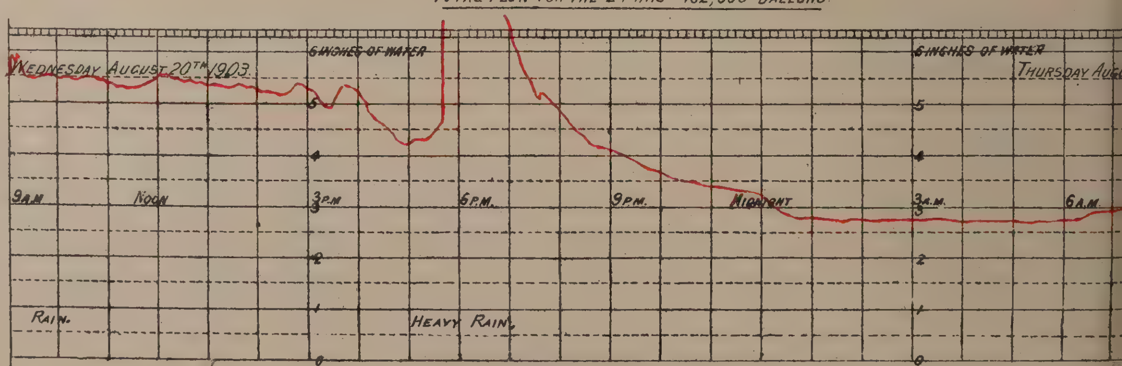
TOTAL FLOW FOR THE 24 HRS. = 288,720 GALLONS

Dry Day.
Rainfall nil.
Following day of heavy rainfall on dry ground.



TOTAL FLOW FOR THE 24 HRS. = 162,500 GALLONS

Rainfall 0·11 inch.
on wet ground.



TOTAL FLOW FOR THE 24 HRS. = OVER 369,960 GALLONS.

Weller & Graham Ltd Lith

these times. As a rough estimate, however, we think that probably 4 or 5 times the dry weather flow of 21,000 gallons per day is the maximum quantity which ever reaches the works.

The flow of sewage has been measured on three occasions; once in March, 1902, over a period of a week; once in August, 1903, over a period of three weeks, and once in July, 1905, over a period of two weeks.

The measurements of March, 1902, resulted in an estimate of the dry weather flow of approximately 190,000 gallons per 24 hours; those of August, 1903, made in wet weather, resulted in an estimate of 250,000 gallons per 24 hours; while the last measurements in July, 1905, resulted in an estimate of 220,000 gallons per 24 hours. Probably, therefore, as an approximate estimate, the average dry weather flow at the works during the whole period of observation was between 200,000 and 220,000 gallons per day.

In dry weather the flow is of an even character, being roughly in the proportion of two volumes in the daytime to one at night, though in long continued dry weather, when the ground water is low, the variations are greater.

When rain falls upon the area, whether the ground is wet or dry, the fluctuations are large, an increase of flow in the proportion of four to one within half an hour being not uncommon. On one occasion, indeed, as the result of a sharp shower on dry ground, a rise in the proportion of seven to one within half an hour was recorded.

With regard to subsoil water, two facts go to show that a considerable quantity finds its way into the sewers. Firstly, the night flow, except in long continued dry weather, is large; and secondly, the flow of sewage remains much swollen for some days after the ground has been once made thoroughly wet by rain. Its actual amount varies, of course, as it depends upon the weather of the preceding weeks.

On diagram T are given some illustrations of the sewage flow at Newton-le-Willows.

Screens.—Before passing into the distribution troughs on the filters, the sewage flows through four screens. These vary in mesh from one inch in the first screen to a quarter of an inch in the fourth. They are cleaned several times a day by being lifted out of the flow and shaken.

Crude Sewage.—Four sets of hourly samples were examined chemically, *viz.*, Nos. 3236, 3637, 3641 and 3646. It was intended to have completed the usual three sets in September, 1903, but after the first day's sampling rain fell heavily and stopped further progress. A second set was therefore taken in July, 1905, during dry weather, excepting for 0·03″ of rain which fell in a heavy sharp shower on the afternoon of Tuesday, July 11th. Two samples of weak night sewage were also drawn at 4.30 a.m. on September 1st, 1903 and July 12th, 1905.

The following results were obtained:—

Parts per 100,000		Average.	Number of Estimations.	Weak Night Sewage. No. 3239.	3644.
Ammoniacal Nitrogen	(3·33)		(1)		
Albuminoid Nitrogen	(0·87)		(1)		
Total Organic Nitrogen	(1·31)		(1)		
Oxidised Nitrogen				0·21 ap.	
Total Nitrogen	(4·64 to 6·15)	5·47	(4)	2·66	1·85
"Oxygen absorbed" at 27°C *at once*	(2·31 to 3·83)	2·93	(4)	0·78	0·69
"Oxygen absorbed" at 27°C *in 4 hours*	(10·25 to 14·37)	11·80	(4)	2·67	2·31
Chlorine	(9·50 to 12·16)	11·17	(4)		6·68
Solids in Suspension	(17·8 to 43·0)	27·4	(4)	4·0	3·9
Solids by Centrifuge (Vols.)	(132·0 to 314·0)	166·0	(3)		19·0
Ratio of Solids in Suspension to Centrifuge Solids	1 : 5·7 to 1 : 8·4	1 : 7·1	(3)		1 : 4·9

Day Sets of Hourly Samples.—Only the day sewage is purified. It was therefore considered advisable to draw, along with the sets of samples of crude sewage extending over 24 hours, four corresponding sets of day samples, without any admixture of night sewage. The numbers of these were 3241 (drawn September 1st, 1903, 9.30 a.m.–5.30 p.m.) and 3638, 3642 and 3647, drawn in July, 1905, from 9.30 a.m. to 5.30 p.m. each day. These gave the following figures :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(4·03 to 4·84)	4·61	(4)
Albuminoid Nitrogen	(1·00 to 1·29)	1·09	(4)
Total Organic Nitrogen	(1·41 to 2·32)	1·79	(4)
Total Nitrogen	(6·17 to 6·82)	6·40	(4)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(2·90 to 4·31)	3·72	(4)
,, ,, ,, ,, *in 4 hours*	(12·43 to 15·98)	14·42	(4)
Chlorine	(11·82 to 13·32)	12·61	(4)
Solids in Suspension	(24·9 to 44·0)	35·20	(4)
Solids by Centrifuge (Vols.)	(222·0 to 359·0)	219·0	(3)
Ratio of Solids in Suspension to Centrifuge Solids	(1 : 8·2 to 1 : 9·4)	1 : 8·8	(3)

If the above figures are compared with those obtained from the average 24 hours' samples of crude sewage, it is seen that the day sewage is distinctly—though not very greatly—stronger than the day and night sewage together. This "day" sewage, though not very nitrogenous, is of more than average strength in oxidizable matter, as measured by the "oxygen absorbed" test; on the other hand the figure for suspended solids is not very high.

In addition to the hourly samples, four chance samples, Nos. 3052, 3128, 676 and 3466, were examined. All these samples were drawn between the hours of 9.50 a.m. and 3.35 p.m., No. 3128 (a weak sample) during heavy rain. The following figures were obtained :—

	Parts per 100,000.	Average.	No. of Estimations.
Ammoniacal Nitrogen	(0·87 to 4·84)	3·28	(3)
Albuminoid Nitrogen	(0·26 to 1·21)	0·79	(3)
Total Nitrogen	(6·24 and 7·83)	7·04	(2)
Total Organic Nitrogen	2·10 and 2·99)	2·05	(2)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(1·60 to 8·03)	5·00	(4)
,, ,, ,, ,, *in 4 hours*	(4·07 to 22·56)	16·13	(4)
Chlorine	(14·04 to 20·70)	16·45	(3)
Solids in Suspension	(11·20 to 33·10)	30·10	(3)
Solids by Centrifuge (Vols.)	(64·0 to 349·0)	246·0	(4)
Ratio of Solids in Suspension to Centrifuge Solids	(1 : 5·7, 6·8 and 10·5)	1 : 7·7	(3)

Taking these chance samples all over, they were somewhat stronger than the hourly sets of sewage samples drawn during the day, that is, they were distinctly strong. The very high proportion of chlorine is noticeable here.

No. 3240 represents a sample of storm water sewage drawn on September 2nd, 1903, at 11.10 a.m., after the overflow had been in operation for 7½ hours. During this time 0·50″ of rain fell, and for the greater part of it the total flow of sewage was at the rate of about 1,000,000 gallons per 24 hours, *i.e.* about five times the normal. This sample had a clean smell and still retained a trace of nitrate when it came to be analysed, but it contained much suspended matter (of which one-third was organic) and failed to withstand incubation. It furnishes a good argument for the settlement of suspended matters from

storm sewage, so far as is practicable, for the greater part of this impurity no doubt lay in the suspended solids. It gave the following figures :—

Total Nitrogen	1·58	
"Oxygen absorbed" at 27° C. *at once*	1·50	
" " " *in 4 hours*	6·02	
Solids in Suspension	29·50	< 10·5 Volatile. 18·4 Non-volatile.

Bacteriological Results.—The results of the bacteriological examination of Newton-le-Willows sewage and trough liquor are shown in the accompanying table. The B. coli, indol, neutral red broth, lactose peptone milk and bile-salt glucose peptone tests practically always gave a positive result with ·00001 c.c. (100,000 per c.c.) The B. enteritidis sporogenes test usually gave a positive result with ·01 to ·001 c.c. (100 to 1,000 per c.c.)

Description of the Sample.	B. coli test.	In.=Indol test. N.R.=Neutral red broth test. L.P.M.=Lactose peptone milk test. B.S.=Bile-salt glucose peptone test.	B. enteritidis sporogenes test.	Remarks.
3052. Newton-le-Willows crude sewage, 18/11/02	100,000 (+ indol) (+ clot)	100,000 In. 100,000 N.R. 100,000 L.P.M. 100,000 B.S.	1,000 not 10,000	"Gas" test, + ·001 c.c. 24 hours at 20°C.
3239. Newton-le-Willows crude sewage, 1/9/03.	100,000 (– indol) (– clot)	100,000 N.R.	10 not 100	
3240. Newton-le-Willows storm sewage, 2/9/03.	—	10,000 not 100,000	100 not 1,000	
3466. Newton-le Willows crude sewage, 6/6/04.	100,000 (+ indol) (+ clot)	100,000 N.R. 100,000 B.S.	1,000 not 10,000	
3227A. Newton-le Willows trough liquor, 1/9/03.	100,000 (+ indol) (+ clot)	100,000 N.R.	1,000 not 10,000	
3467. Newton le Willows trough liquor, 6/6/04.	100,000 (+ indol) (+ clot)	100,000 N.R. 100,000 B.S.	100 not 1,000	

Trough Liquors.—Five sets of *day* average samples, Nos. 3237A, 3242, 3639, 3643 and 3648, and one chance sample, No. 3467, were examined chemically. Two sets of the *day* average sample were drawn in September, 1903, and three in July, 1905, in dry weather, excepting for the heavy shower on Tuesday, July 11th, already alluded to. They gave the following results on analysis :—

	Parts per 100,000.	Average.	Number of Estimations.	Chance Sample No. 3467.
Ammoniacal Nitrogen	(4·35 to 4·98)	4·74	(3)	4·83
Albuminoid Nitrogen	(0·81 to 1·22)	1·05	(3)	1·21
Total Organic Nitrogen	(1·66 to 2·56)	2·00	(3)	2·65
Total Nitrogen	(6·64 to 6·91)	6·74	(3)	7·48
"Oxygen absorbed" at 27° C. *at once*	(3·15 to 4·66)	3·71	(4)	4·65
" " " " *in 4 hours*	12·34 to 16·76)	13·60	(5)	18·43
Dissolved Oxygen taken up in 24 hours at about 22° or 23° C.	(29·1 to 49·5)	39·4	(3)	
Chlorine	(13·00 to 13·80)	13·42	(3)	13·52
Solids in Suspension	(23·5 to 48·8)	30·3	(5)	30·7
Solids by Centrifuge (Vols.)	(217·0 to 402·0)	282·0	(3)	296 0
Ratio of Solids in Suspension to Centrifuge Solids	(1 : 8·2 to 1 : 9·2)	1 : 8·6	(3)	1 : 9·6

If these figures of analysis be compared with those given by the hourly day samples of crude sewage, it will be seen that, excepting for a very slight settlement of solids, there is practically no difference between them. The filter beds at Newton are therefore called upon to treat a very slightly settled sewage of more than average strength, and containing about 30 parts of suspended solids.

CONTACT BEDS.

Number - - - - - - - -	6.
Size - - - - - - - - -	2 beds, 60 feet by 20 feet.
	4 beds, 44 feet by 20 feet.
Total area - - - - - -	657 square yards.
Total cubic content - - - - -	767 cubic yards.
Depth of material - - - - -	3 feet 6 inches.

Material. —3 feet of boiler furnace clinker, raised 6 inches from the floor of the bed on honeycomb brick-work.

Grading, from Top, downwards.—1 foot 6 inches, clinker $\frac{1}{2}$ inch to $\frac{1}{4}$ inch diameter; 1 foot 6 inches, clinker 2 inches to $1\frac{1}{2}$ inch diameter; and 6 inches honeycomb brickwork.

Construction. —Cement and blue bricks.

Distribution. —2 wooden troughs, 9 inches deep and 18 inches wide, extending the length of each bed.

(Note.—These troughs are cleaned out about three times a week. They therefore serve for the settlement of a small part of the suspended matter in the sewage.)

Working.—The beds are filled in rotation from 8.30 a.m. to 5.30 p.m. each day. In the early part of their life, a two hours' contact was given, but during our observations it has usually lasted for not more than one hour. The distribution troughs are cleaned out three times a week, by sweeping the sludge which has then accumulated in them into a pail let into the material at the end of each trough. When the pails are full, they are lifted out and emptied on to a heap of dry sludge at the side of the filters.

Capacity.—The original empty tank capacity of the six filters was 129,500 gallons. Assuming that the new material would occupy one-half of the space of the tank, it is estimated that the original water capacity of the six beds was approximately 64,750 gallons. From July, 1900, when they were first brought into use, until March 24th, 1902, when our first capacity measurements were made, the beds received on an average 1·5 fillings per day of grit-settled sewage. On March 24th, 1902, capacity measurements made on bed A as typical of the two larger beds, and bed B taken as typical of the four smaller ones, gave 46,800 gallons as the total water capacity at this time. After a period of twenty months work, therefore, the water capacity of the beds was 36 per cent. of the original empty tank capacity, or 72 per cent. of the original water capacity. In the first five months of the observations, the original rate of working the beds was adhered to, 1·66 fillings per day being given on the average to each bed. On September 8th, 1902, however, it was determined to increase the rate of filtration, in order to obtain data as to the working limit of the beds; and from that time, night sewage as well as day sewage was treated upon them.

It was intended at first to work the beds at the increased rate for several months, but by December 7th the beds appeared to be so clogged and sodden upon the surface and were worked with such difficulty, that it was thought advisable to stop. The experiment lasted, therefore, about 3 months (September 8th to December 7th), and during this time the beds received an average of 2·48 fillings per day, or 126·5 gallons per cube yard per day. On re-gauging (December 7th, 1902), the total capacity after the experiment was found to be 41,840 gallons, or 32 per cent. of the original empty tank capacity. The appearance of the beds would have suggested a much greater loss in capacity than this, and the result, therefore, is the more interesting as showing that the clogging did not extend very far below the surface of the material.

Although the 2·48 fillings given to the beds do not seem an excessive quantity, the beds were obviously called upon to receive suspended matter at too great a rate; the old plan of working them only in the daytime was therefore reverted to, and from December 7th, 1902, to September 3rd, 1903, the beds received on an average only 1·67

fillings per day. At the end of this time, on September 3rd, 1903, the capacity was found to have risen to 45,000 gallons, or 35 per cent. of the original empty tank capacity, thus showing that the beds had almost recovered themselves. Another measurement, however, made on May 30th, 1905 after a further period of 21 months, working at an average rate of 1·73 fillings per day, gave the capacity as 35,000 gallons, or 27·4 per cent. of the original empty tank capacity.

Worked therefore at an average of rather more than 1½ fillings per day, the beds have lasted about five years. If 20 per cent. of the original water capacity is taken as the lowest practical limit of capacity reduction, they can probably go on for a few months longer; but we think the last measurement indicates that the time for washing or renewing the material in the beds was not far off.

Amount of Sewage Treated.—Except during the period of three months when an increased number of fillings was given to them, the beds have been filled on an average 1·7 times per day during the whole of our observations. The mean water capacity during the same period has been 41,150 gallons, and the average amount treated throughout this time has therefore been as follows:—

Per square yard per 24 hours - - - - 106 gallons.
Per cube yard per 24 hours - - - - 91 gallons.

During the experiment with the increased number of fillings per day, the rate of filtration was:—

Per square yard per 24 hours - - - - 168 gallons.
Per cube yard per 24 hours - - - - 144 gallons.

Effluents.—Two sets of hourly samples (of 24 and 12 hours respectively), Nos. 3238B and 3243, and 6 chance samples, Nos. 3053, 3128A, 3468, 3636, 3640 and 3645, were examined.

The hourly samples, drawn in dry weather in August, 1903, were made up of equal quantities of liquid from all the emptyings of all the beds for the day, taken at mid flow, each bed being filled twice. They gave the figures:—

Parts per 100,000.	No. 3238B.	No. 3243.
Ammoniacal Nitrogen	3·56	3·24
Albuminoid Nitrogen		
Oxidized Nitrogen	about 0·25	Doubtful trace.
Total Nitrogen	4·09	4·00
Total Organic Nitrogen	?	0·73
"Oxygen absorbed" at 27° C. (80° F.) *at once*	1·62	1·71
" " " " *in 4 hours*	6·88	6·70
Chlorine	11·12	11·52
Solids in Suspension	7·50	9·50
Incubator test (Scudder)	—	—
Incubator test (by smell)	—	—
Smell when drawn	—	—
Smell when analysed	—	—

These hourly effluent samples were thus very far from being purified. Although too few in number for a proper criticism, the reduction on the hourly samples of sewage shows:—

Calculated on the "Oxygen absorbed" *at once* - 50 per cent.
" " " " *in 4 hours* 49 "
" Suspended Solids - - - - - 72 "

Chance Effluents.—Of the six chance samples of effluent examined chemically, Nos. 3053, 3128A, 3468, 3636, 3640 and 3645, the first two were drawn in November, 1902, and March, 1903, the third in June, 1904, and the last three in July, 1905. They were thus mostly summer samples, taken when the sewage was strong, and, excepting in the case of No. 3128A (an effluent from the treatment of dilute storm sewage), they were all drawn in dry weather.

The following results were obtained :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(0·72 and 0·46)	—	(2)
Albuminoid Nitrogen	(0·17 and 0·56)	—	(2)
Oxidized Nitrogen	(0·0 to 0·98)	0·16	(6)
Total Nitrogen	(2·62 to 5·00)	4·20	(3)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(0·88 to 2·04)	1·61	(6)
,, ,, ,, ,, ,, *in 4 hours*	(2·80 to 8·46)	5·78	(6)
Dissolved Oxygen taken up in 24 hours at about 18° C.	(1·19 to 15·1)	6·18+x†	(5)
Chlorine	(6·70 to 16·80)	12·99	(5)
Solids in Suspension	(4·32 and 9·50)		(2)
Solids by Centrifuge (vols.)	(25·0 to 84·0)	52·0	(6)
Ratio of Solids in Suspension to Centrifuge Solids	1 to 10·7 and 1 : 8·8		(2)
Incubator test (Scudder)		1+	(1)
Incubator test (by smell)		*6—	(6)
Smell when drawn		2+3—	(5)
Smell when analysed		1+4—	(5)

Like the hourly samples of effluent, these chance samples were of very poor quality, the best being No. 3128A, an effluent resulting from one hour's contact of the dilute storm sewage, No. 3128. It was the only effluent examined which contained any oxidized nitrogen on the day of analysis (0·68 part nitrous and 0·23 part nitric nitrogen). As compared with the sewage, No. 3128, it showed the following reduction in figures :—

"Oxygen absorbed" *at once*	29	per cent. reduction.
,, ,, *in 4 hours*	31	,, ,,
Solids in Suspension	71	,, ,,

Taking the six chance samples of effluent together, they were for the most part brown and turbid, with considerable quantities of suspended solids (fully 5 parts on the average, as reckoned from the centrifuge figures), and all but one had more or less of a sewage smell when drawn and also when analysed. Compared with the five hourly day sets of samples of trough liquor, they show the following reduction in figures :—

"Oxygen absorbed" *at once*	57	per cent. reduction.
,, ,, *in 4 hours*	57	,, ,,
Solids in Suspension (as reckoned mainly from the centrifuge figures)	·80	,, approx.

Bacteriological results.—The results of the bacteriological examination of the contact bed effluents are shown in the accompanying table. Generally speaking, the B. coli. indol, neutral red broth, lactose peptone milk, and bile-salt glucose peptone tests yielded

* It was considered unnecessary to incubate some of the samples.

† "6·18+x" means "at least, 6·18."

positive results with ·00001 c.c. (100,000 per c.c). The B. enteritidis sporogenes test gave a positive result with ·01 c.c. (100 per c.c.) in three out of five samples examined.

Description of the Sample.	B. coli test.	In. = Indol test. N.R. = Neutral red broth test. L.P.M. = Lactose peptone milk test. B.S. = Bile salt glucose peptone test.	B. enteritidis sporogenes test.	Remarks.
3053. Newton-le-Willows contact bed effluent, 18/11/02.	100,000 (+ indol) (+ clot)	10,000 not 100,000 In. 100,000 N.R. 10,000 not 100,000 L.P.M. 100,000 B.S.	100 not 1,000	"Gas" test + ·001 c.c. 24 hours at 20°C.
3128A. Newton-le-Willows contact bed effluent, 18/3/03.	—	100,000 N.R.	10 not 100	
3228B. Newton-le-Willows contact bed effluent, 1/9/03.	100,000 (+ indol) (+ clot)	100,000 N.R.	100 not 1,000	
3233. Newton-le-Willows contact bed effluent, 2/9/03.	—	100,000 N.R.	100 not 1,000	
3468. Newton-le-Willows contact bed effluent, 6/6/04.	100,000 (+ indol) (+ clot)	100,000 N.R. 100,000 B.S.	1,000 not 10,000	

Effect of Temperature upon the Working of the Beds.—Not many measurements of temperature have been made at Newton for the Commission, but, so far as they go, they indicate that the working of the beds is not affected to any extent by the ordinary variations in temperature of the atmosphere or the sewage.

SUMMARY.

The main object in selecting Newton-le-Willows as a place for observation, was to study the effect of treating slightly settled crude sewage of a slop water character, from a somewhat small community, upon single contact beds, the installation being of a simple and inexpensive character.

The day sewage at Newton, though not containing a high proportion of nitrogen, is of more than average strength as regards oxidizable matter, measured by the "oxygen absorbed" test; and, excepting for a slight settlement of suspended solids, the trough liquor is of the same composition as the day sewage.

Apart from the question of grit, the settlement effected by the troughs was very small, something like 30 parts per 100,000 of suspended solids being left to go on to the beds.

It was not of course to be expected that sewage so strong as this could be treated on single contact beds, at the rate of about 90 gallons per cubic yard per day, so as to yield a reasonably pure effluent. Indeed it is difficult to see how a satisfactory effluent could be obtained from such a sewage by single contact, under practical conditions of working. At the same time, the treatment did remove a very large proportion of the impurity of the sewage.

With an average of $1\frac{1}{2}$ fillings of trough liquor per day, the beds have, so far, lasted for five years. So long as this rate of working was adhered to, the beds maintained their capacity well, but an increased rate of $2\frac{1}{2}$ fillings per day resulted, in so short a time as two months, in bringing the surface of the beds into such a sodden condition that

they would soon have become unworkable, if the old rate had not been reverted to. That the clogging was mainly confined to the surface of the beds was clearly shown by the subsequent capacity measurements.

Had the material on the surface of the beds been larger, the prejudicial effect of the increased number of fillings would have been longer in showing itself; but, on the other hand, this effect would have been more permanent, in that the beds would have lost capacity throughout, and not merely in the surface layers.

A point of special interest is that, excepting when the screens are taken up out of the sewage channels, there is practically no smell attending this method of sewage treatment. Further, it may be noted that under the existing conditions, the day (slop-water) sewage from a population of about 9,000 persons has been purified to a considerable extent for five years at small outlay. The tanks (which are now the filters) originally cost about £500, and were subsequently filled with clinker, at a further outlay of £160, while the working expenses have amounted to about £72 per annum. Without, therefore, modifying what has already been said with regard to the quality of the effluents at Newton, the foregoing facts indicate that the treatment of the sewage of a small town need not necessarily be upon very expensive lines.

We are indebted to Mr. Arthur Bowes, Surveyor to the Newton-in-Makerfield Urban District Council, and to Mr. Ernest Haynes, Manager of the Sewage Works, for help in connection with our work at Newton.

NORMANTON SEWAGE WORKS.

(NORMANTON URBAN DISTRICT COUNCIL.)

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1. Situation of works - - - - - -	Rather more than a mile from the main body of the population.
2. Methods of treatment - - - - -	(1) Day sewage on Tuesdays, Wednesdays and Fridays: chemical precipitation, continuous flow subsidence, and filtration through percolating beds of very fine material (International process). (2) Day sewage on Mondays, Thursdays, Saturdays and Sundays, and all night sewage: chemical precipitation and continuous flow subsidence, followed by filtration through land.
3. Population draining to works during observations - - - - - - - -	12,600 (estimated average).
4. Water supply in gallons per head and whence obtained - - - - - - -	13. Wakefield Corporation water supply—a soft moorland water.
5. Number of W.C.'s - - - - - -	250.
6. Sewerage system - - - - - -	Combined.
7. Average dry weather flow of sewage in gallons per 24 hours - - - - - -	175,000.
8. Gallons of sewage per head per day - -	13·9.
9. Character of the sewage - - - - -	Very soapy domestic sewage, consisting chiefly of slop-water.
10. Period of observations - - - - -	1903 and 1904.
11. Age of filters - - - - - - -	18 years. The filters were first used in 1885.
12. Amount of storm water treated on filters during observations - - - - - -	Practically none; that is to say, the volume of sewage liquor treated in the filters is almost constant.
13. Total capacity of tanks in gallons - - -	101,250.
14. Total area of filters in yards super - - -	161·3.

15. Total cubic content of filters in yards cube - 174·8.

16. Nature of filtering material - - - - Gravel, river sand and polarite.

17. Gallons of precipitation liquor treated per yard super per 24 hours (all filters included) - - 106·2.

18. Gallons of precipitation liquor treated per yard cube per 24 hours (all filters included) - - 98.

19. The final effluent is discharged into - - The Waindyke Beck, a polluted stream forming a tributary of the river Calder.

FLOW OF SEWAGE.

As the sewerage of the district is upon the combined system, large volumes of storm water gain access to the sewers in times of rain. Some of this is diverted to the Wain Dyke and to the Ashfield Beck over the three overflows in the system; but as the main sewer occasionally runs full bore, a flow at the rate of approximately 1,500,000 of gallons per day can reach the works. We have ourselves measured a rate of flow equivalent to this, and also a 24 hours' flow during a rain-fall of ·72 inches of approximately 800,000 gallons. At such times, however, the excess over three or four times the dry weather flow of 175,000 gallons per day is diverted by means of a by-pass to the Wain-Dyke Beck, and the amount treated may therefore be said to seldom exceed 600,000 gallons per day.

Continuous daily measurements of the total (high and low level) flow of sewage were made over a period of two months in February and March, 1904. During this time there were two short periods of dry weather, one lasting a fortnight and the other a week, and the average daily flow throughout each of these was approximately 175,000 gallons per day. Probably, notwithstanding the dry weather, the flows at this time of the year would still be affected by the winter rains, and this figure of 175,000 gallons per day, which for the purposes of calculation has been taken as the dry weather flow, may therefore be somewhat too high, although from the water supply and from the fact that the sewers are known to leak in several places, it cannot be very much so.

During dry weather, except at the three times in the day when the low level sewage is pumped up into the main inlet channel, the flow is of an even character, varying gradually from a minimum rate of 240,000 gallons per 24 hours to a maximum rate (in winter) of 350,000 gallons per 24 hours. The pumping which takes place three times a day, at 7.30 a.m., 2 p.m., and 4 p.m., causes a sudden rise up to a rate of rather more than 400,000 gallons per 24 hours.

In showery weather or when heavy rain occurs, the variations are much greater and considerably more rapid; but during times of continued rain the ordinary variations are masked in a steady and even storm flow. The greatest variation measured during the gaugings was a rise of flow in the proportion of nine to one within two hours.

On Diagram U. are given illustrations of the sewage flow at Normanton.

Subsoil Water.—Throughout the whole of the dry weather gaugings, the night flow was a practically constant one at the rate of about 50,000 gallons per day, and it is therefore evident that, during the winter months at any rate, large quantities of subsoil water gain access to the sewers in dry weather.

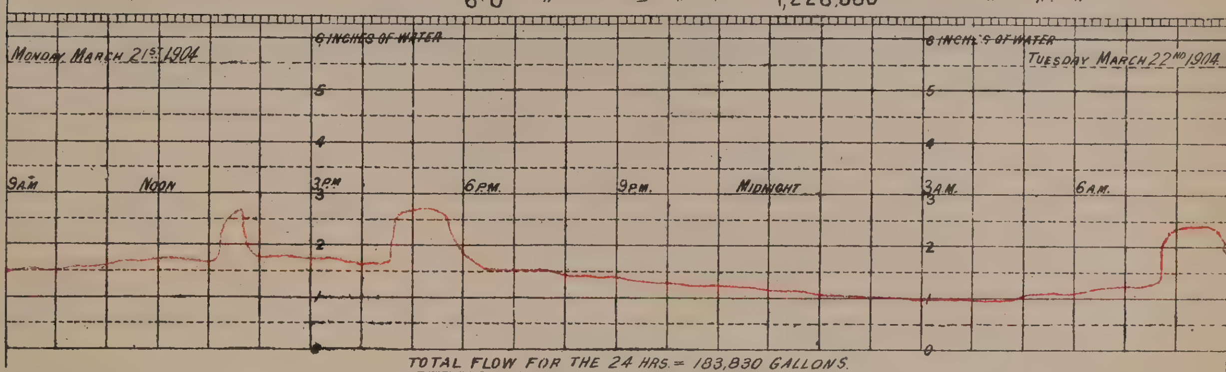
Diagram U.

Diagrams showing flow of Sewage at Normanton as falling over a Weir 24" wide.

Note:- Over a Weir 24" wide

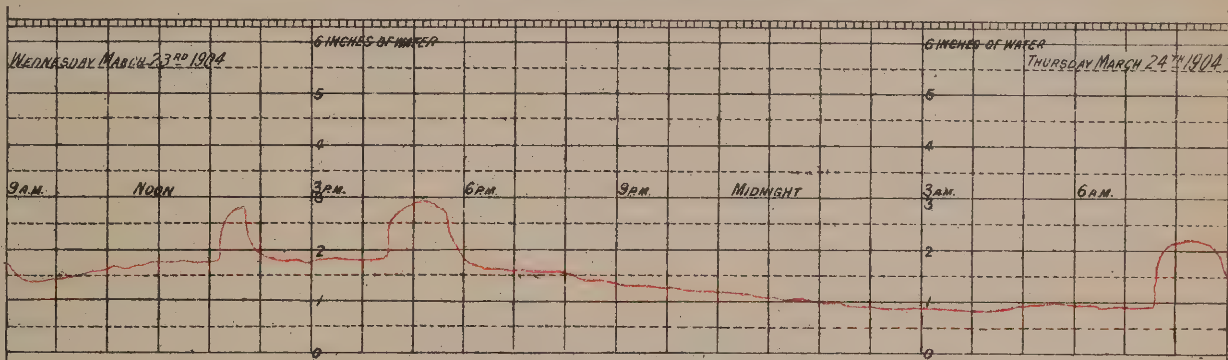
1·0 inch	=	a rate of 85,000	gallons per 24 hours.
2·0 inches	=	" " " 240,300	" " " "
3·0 "	=	" " " 436,320	" " " "
4·0 "	=	" " " 671,040	" " " "
5·0 "	=	" " " 933,120	" " " "
6·0 "	=	" " " 1,226,880	" " " "

RY DAY.
AINFALL NIL.



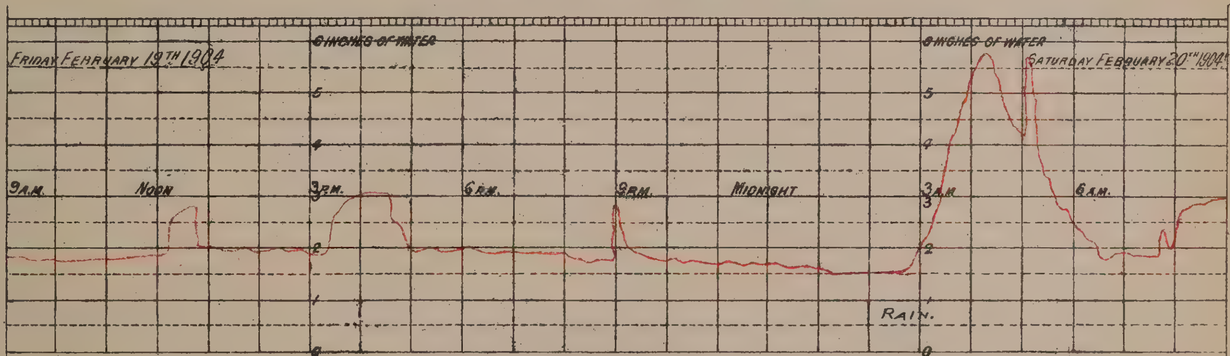
TOTAL FLOW FOR THE 24 HRS. = 183,830 GALLONS.

RY DAY.
INFALL NIL.



TOTAL FLOW FOR THE 24 HRS. = 183,080 GALLONS.

LL 0·08 INCH.

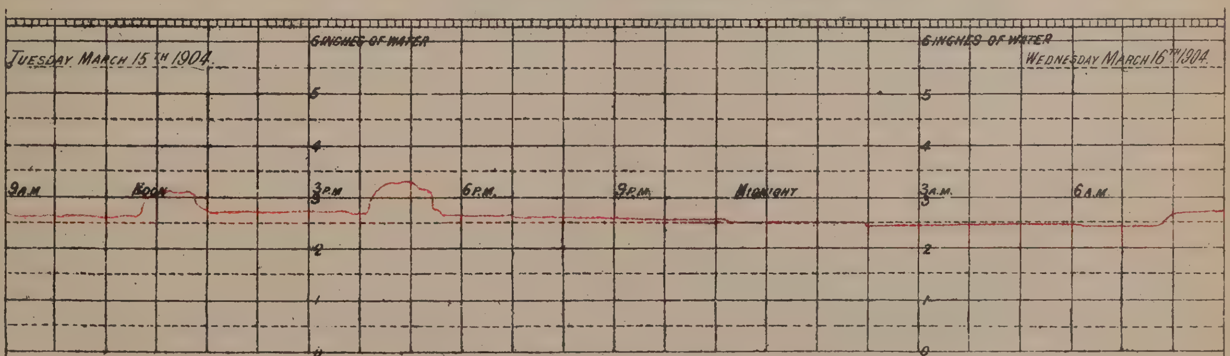


TOTAL FLOW FOR THE 24 HRS. = 298,235 GALLONS.

ET DAY.
L 0·40 INCH.

TOTAL FLOW FOR THE 24 HRS. = MORE THAN 550,000 GALLONS.

OLLOWING TWO
VY RAINFALL.
ALL NIL.



TOTAL FLOW FOR THE 24 HRS. = 393,500 GALLONS.

Note:- The almost regular increases of flow which take place at about noon, 5 p.m. & 8 a.m. at Normanton are due to the pumping of a small portion of the sewage.

Weller & Graham. Ltd Litho London.

Crude Sewage.—Five samples were examined chemically, three hourly and two chance. The sets of hourly samples, Nos. 3434, 3438 and 3442A, extending over the usual three days, were drawn on March 21st–24th, 1904; during this time the weather was dry, excepting for a heavy shower on the evening of the 22nd. A chance sample of night sewage was also taken on Wednesday, March 23rd, 1904, at 4.30 a.m. The figures for the only other sample of sewage examined, No. 3129, drawn on Tuesday, March 24th, 1903, at 3.30 p.m., may also be given here; this last sample was taken on Tuesday (washing day), during a period of dry weather, excepting for a few showers on the Monday.

The following results were obtained:—

Parts per 100,000.		Average.	Number of Estimations.	Night Sewage, No. 3,442.	Chance Sample, No. 3,129.
Ammoniacal Nitrogen	(6·49 to 7·85)	6·95	(3)	4·84	9·20
Albuminoid Nitrogen	(1·26 to 1·69)	1·50	(3)	0·76	1·89
Total Organic Nitrogen	(1·93 to 3·80)	3·09	(3)	0·81 (?)	—
Oxidized Nitrogen		0·0	(3)	0 0	—
Total Nitrogen	(8·43 to 11·65)	10.04	(3)	5·65	—
"Oxygen absorbed" at 27° C. *at once*	(3·87 to 7·73)	6·34	(3)	1·71	9·69
" " " " *in* 4 *hours*	(19·59 to 35·17)	29·25	(3)	7·03	49·07
Chlorine	(13·82 to 19·18)	15·87	(3)	11·98	—
Solids in Suspension	(29·9 to 75·7)	55·0	(3)	21·70	117·7
Solids by Centrifuge (vols.)	(275·0 to 519·0)	415·0	(3)	113·0	Too coarse.
Ratio of Solids in suspension to Centrifuge Solids	(1 : 6·9 to 1 : 9·2)	1 : 7.9	(3)	1 : 5·4	

The above figures show that the crude sewage at Normanton is organically very strong, though perhaps the conditions under which the samples were drawn tended to accentuate this. The first hourly set, No. 3434, was taken on Monday–Tuesday, on a dry day after fairly dry weather. While the second hourly set, No. 3438, was being drawn, a heavy shower, amounting to 0·03″ rainfall, occurred on the Tuesday evening, and this evidently had the effect of washing considerable quantities of solids out of the sewers, two of the hourly fractions being very dark from storm water; for the same reason the chance sample of weak night sewage, No. 3442, was also probably affected. The third hourly set, No. 3442A, was drawn on Wednesday–Thursday in dry weather, but on slaughtering day. The chance sample, No. 3129, was taken, as already stated, on a washing day in March, 1903.

In appearance these samples were soapy and turbid, and they all, even the weak night sample, had a more or less strong soapy smell. The suspended solids in the chance sample, No. 3129, amounted to as much as 118 parts and were very coarse in character. Even making every allowance, therefore, for the circumstances mentioned above, there can be no question as to the great strength of this dry-weather sewage. It will be noted that the night sample was unusually strong, this being due to Normanton having a large mining and railway population, part of whom work during the night.

Bacteriological Notes.—Two samples (Nos. 3129 and 3442) were examined bacteriologically. The B. coli test and presumptive tests for B. coli yielded positive results with ·00001 c.c. (100,000 per c.c.) in the case of sample 3129. Sample 3442 yielded lower results, but this was a sample of night sewage. As regards the B. enteritidis sporogenes

test, sample 3129 yielded a positive result with ·001 c.c. (1000 per c.c.) and sample 3442 with ·1 c.c. (10 per c.c.).

Description of the Sample.	Number of B. Coli (or gas-forming Coli-like microbes).	B.S. = Bile-salt glucose peptone test. N.R. = Neutral red broth test. In. = Indol test. L.P.M. = Lactose peptone milk test.	B. Enteritidis Sporogenes test.	Remarks.
3129. Normanton crude sewage, 24/3/03.	100,000 (+ indol) (– clot)	100,000 B.S. 100,000 N.R. 100,000 In.	1,000 not 10,000	
3442. Normanton crude sewage, night sewage, 23/3/04.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R.	10 not 100	

SCREEN.

As it flows to the tanks, the sewage passes a 1″ screen. This is raked once a day, and the screenings are tipped into the sludge lagoon.

PRECIPITATION TANKS.

Number	3.
Size	30′ by 30′.
Depth of water	6′.
Capacity of each	33,750 gallons.
Total capacity	101,250 gallons.

Construction.—The tanks are contructed of brick and cement walls with concrete bottoms. They are fitted with sludge valves and floating arms.

Precipitant.—The precipitant used is Alumino-ferric. It is added in the form of a block, placed in the main inlet channel. In the years 1903 and 1904 the quantities used were 25 tons and 30 tons respectively, and on the basis of the dry weather flow, this is equivalent to about 6·7 grains per gallon.

Flow through.—With a dry weather flow of 175,000 gallons per 24 hours, the flow through the three tanks would be once in 14·7 hours, at the rate of 1·22 inches per minute.

Working.—The tanks are used in series, and as a rule all three are in use at the same time; but during the sludging which occurs every week, two tanks are kept working while the third is being sludged.

Sludging.—On Thursday of every week all three tanks are emptied and cleaned. The operation is carried out as follows :—

After the supernatant liquid has been drawn off by means of the floating arms, the sludge gravitates or is pushed to a sludge sump, from which it is lifted by means of a valve pump worked by a gas engine and delivered to one or more of the sludge lagoons. The supernatant liquor is filtered on an area of about a quarter of an acre of low-lying land.

The sludge lagoons cover an area of approximately a quarter of an acre, and are constructed by simple excavation in the heavy soil, being drained by means of agricultural pipes laid at the bottom of grips, 18″ deep, cut in the soil. They also drain on to the plot of land which receives the tank liquor when the tanks are emptied for sludging.

In the lagoon the sludge is allowed to dry naturally; but the process, especially in wet weather, is an extremely slow one, and it is usually some months before the sludge is dry enough to be removed. When it is dry, however, there is little difficulty in disposing of it, and it is either given away to farmers or put upon a neighbouring field which is rented by the Council. A considerable nuisance arises from the sludge as it dries in the lagoons.

Precipitation Liquor.—Six sets of hourly samples and seven chance samples of precipitation liquor were examined chemically. The hourly samples were drawn on March 21st–24th, 1904, on the same days as the hourly samples of sewage. They were taken in two series of three sets each, Series A representing the whole 24 hours' flow of precipitation liquor, and therefore corresponding to the hourly samples of sewage, while Series B represents the precipitation liquor drawn during the nine day hours (9.30 a.m.–5 30 p.m. inclusive), and corresponds to the hourly samples of effluent.

The following results were obtained :—

Series A. (Hourly Samples Nos. 3,435, 3,439, 3443.)	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(4·80 to 6·06)	5·46	(3)
Albuminoid Nitrogen	(0·65 to 0·93)	0·80	(3)
Total Organic Nitrogen	(1·70 to 2·38)	2·04	(3)
Oxidized Nitrogen		0·0	(3)
Total Nitrogen	(6·50 to 8·44)	7·49	(3)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(1·95 to 4·63)	3·23	(3)
,, ,, ,, ,, *in 4 hours*	(9·48 to 15·54)	12·98	(3)
Chlorine	(13·30 to 15·30)	14·33	(3)
Solids in Suspension	(13·3 to 20·3)	17·9	(3)
Solids by Centrifuge (vols.)	(96·0 to 115·0)	108·0	(3)
Ratio of Solids in Suspension to Centrifuge Solids	(1 : 5·6 to 1 : 7·2)	1 : 6·2	(3)

The above samples of precipitation liquor, like the corresponding samples of sewage, increased in strength from the Monday to the Wednesday, though this increase was, of course, less marked in the case of the precipitation liquor. The samples were all brown coloured and turbid, with a somewhat sour smell, the quantity of suspended matter present in them (17·9 parts on the average) being very large. In every respect the dry weather precipitation liquor for the whole day at Normanton is a very strong one.

As compared with the hourly samples of sewage, they show the following reduction in figures :—

Calculated on :—

Total Nitrogen	25	per cent. reduction.
Albuminoid Nitrogen	47	,, ,,
Total Organic Nitrogen	34	,, ,,
"Oxygen absorbed" *at once*	49	,, ,,
,, ,, *in 4 hours*	56	,, ,,
Solids in suspension	67	,, ,,
Solids by centrifuge (vols.)	74	,, ,,

Series B. (Hourly Samples Nos. 3436, 3440, 3444).	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(4·18 to 5·75)	4·90	(3)
Albuminoid Nitrogen	(0·56 to 0·80)	0·68	(3)
Total Organic Nitrogen	(1·47 to 1·99)	1·79	(3)
Oxidized Nitrogen		0·0	(3)
Total Nitrogen	(5·65 to 7·74)	6·75	(3)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(1·46 to 3·54)	2·44	(3)
,, ,, ,, ,, *in 4 hours*	(7·10 to 12·96)	10·32	(3)
Chlorine	(12·76 to 14·88)	13·58	(3)
Solids in Suspension	(10·60 to 15·80)	14·00	(3)
Solids by Centrifuge (vols.)	(101·0 to 112·0)	107·0	(3)
Ratio of Solids in Suspension to Centrifuge Solids	1 : 6·4 to 1 : 10·3)	1 : 7·9	(3)

A comparison of these figures with those of Series A shows that the day precipitation liquor is not quite so strong as the liquor taken over the whole 24 hours of the day and night together. The difference is not very great, but still it is quite appreciable all through ; it is noteworthy that the suspended solids only averaged 14 parts, against 17·9 parts in the 24-hours samples. This day dry-weather liquor, however, is still a strong one for the filters to treat. The reason for its being less strong than the 24-hours' sample is that it contains a large proportion of the liquor from the precipitated night sewage.

In addition to the hourly samples, seven chance samples of precipitation liquor, Nos. 3130, 3224, 3265, 3281, 3358, 3365 and 3385A, were examined. With the exception of one, these were all drawn in the cooler months of the year, between the hours of 10 a.m. and 3.35 p.m., and, excepting for two practically dry-weather samples, they were all taken after either showery or wet weather. They therefore vary greatly in composition, but may probably be taken generally as representing something like the average liquid treated on the filters.

The following results were obtained :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(2·27 to 7·04)	4·81	(4)
Albuminoid Nitrogen	(0·40 to 0·68)	0·54	(4)
Total Organic Nitrogen	(0·98 to 1·47)	1·21	(3)
Oxidized Nitrogen	(0·30 and 0·94 in two samples)	—	—
Total Nitrogen	(3·99 to 8·51)	5·68	(6)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(1·07 to 3·58)	1·80	(7)
" " " " *in 4 hours*	(4·74 to 11·18)	7·68	(7)
Chlorine	(10·28 to 17·74)	12·86	(5)
Solids in Suspension	(2·70 to 13·80)	7·40	(6)
Solids by Centrifuge (vols.)	(18·0 to 107·0)	54·0	(7)
Ratio of Solids in Suspension to Centrifuge Solids	(1 : 5·1 to 1 : 12·7)	1 : 9·1	(6)

All these samples had a soapy or tank smell on the day of analysis, excepting No. 3265, which was drawn after heavy rain ; that sample had an earthy smell, but failed to withstand incubation. The large quantity of oxidized nitrogen—0·94 part—found in No. 3,385A, another (rather dilute) sample taken after rain, shows that considerable subsoil water gains access to the sewers. The suspended matter in these chance samples averaged 7·4 parts and was of a flocculent character. It will be observed that the chlorine figurefor all the samples of sewage and precipitation liquor was decidedly high.

The chance samples of precipitation liquor are, therefore, on the average, distinctly weaker than the hourly day samples (Series B). Still, it is evidently a comparatively rare thing for the filters to have a weak tank liquor to treat.

A comparison between these chance samples of precipitation liquor and the hourly samples of sewage is not of much value, but one or two reduction figures may be given :—

Calculated on :—		
Total Nitrogen	43	per cent. reduction.
"Oxygen absorbed" *at once*	72	" "
" " *in 4 hours*	74	" "
Solids in suspension	87	" "

Bacteriological Notes.—Seven samples were examined bacteriologically. Excluding sample 3385A, all the samples yielded positive results with from ·0001 c.c. to ·00001 c.c. 10,000 to 100,000 per c.c.) with the B. coli test and presumptive tests for B. coli. The

B. enteritidis sporogenes test yielded positive results with fr ·1 c.c. to ·01 c.c. (10 to 100om per c.c.). Sample 3,385A yielded lower results with the B. coli and neutral red broth tests (+·001 c.c.; —·0001 c.c.), but higher results with the B. enteritidis sporogenes test (+·001 c.c.). Possibly these results are to be ascribed to rain having fallen during several days previous to the collection of the sample and to the presence of road "washings," which would be likely to alter the ordinary ratios of B. coli and B. enteritidis sporogenes.

Description of the Sample.	Number of B. Coli (or gas forming Coli-like microbes).	B.S.=Bile salt glucose peptone test. N.R.=Neutral red broth test. In.=Indol test. L.P.M.=Lactose peptone milk test.	B. Enteritidis sporogenes test.	Remarks.
3130. Normanton precipitation liquor, 24/3/03.	100,000 (+ indol) (− clot)	100,000 B.S. 100,000 N.R. 100,000 In.	100 not 1,000	
3281. Normanton precipitation liquor, 31/10/03.	100,000 (− indol) (− clot)	100,000 N.R.	10 not 100	
3365. Normanton precipitation liquor, 22/1/04.	100,000 (+ indol) (− clot)	100,000 N.R.	100 not 1,000	
3385A. Normanton precipitation liquor, 15/2/04.	1,000 not 10,000 (+ indol) (+ clot)	1,000 not 10,000 N.R.	1,000 not 10,000	
3435. Normanton precipitation liquor, 22/3/04.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R.	100 not 1,000	
3439. Normanton precipitation liquor, 23/3/04.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R.	10 not 100	
3443. Normanton precipitation liquor, 24/3/04.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R.	10 not 100	

FILTERS.

Number - - - - -	3
Size of each - - - -	22′ by 22′.
Area of each - - - -	484 square feet.
Total area - - - -	161·3 square yards.
Depth of material - - -	3′ 3″.
Cubic content of each - -	1,573 cube feet.
Total cubic content - -	174·8 cube yards.
Material—top - - - -	12″ sand.
,, middle - - -	12″ polarite and sand, mixed.
,, bottom - - -	15″ pebbles, varying from 4″ to ½″ diameter.
Construction - - - -	Brick and cement walls with concrete bottoms.
Distribution - - - -	One iron channel laid down the centre of each bed.
Underdraining - - - -	Eleven lines of 3″ agricultural pipes, connecting to one 6″ main drain.

Age of Beds.—The beds were put down in 1885, their original composition—from the top downwards being 12″ sand, 12″ polarite and sand, 3″ sand, and 15″ pebbles; but the 3″ of sand between the polarite and the gravel gradually became choked, and this was, therefore, removed in 1897.

Working.—The filters are used on three days in the week only (Tuesdays, Wednesdays and Fridays), two filters being in use at one time and the other resting. When in use they receive precipitation liquor from 9 a.m. in the morning to 4 p.m. in the afternoon, and are rested at night and all day on Mondays, Thursdays, Saturdays and Sundays.

At the end of a period of 7½ hours work, the surfaces of the two filters which have been used are swept over with a brush while still under water, and are then allowed to drain until they are again brought into use.

A more complete cleaning takes place every three months, when each bed is washed by an upward flow of filter effluent, obtained by delivering tank liquor on to the two other beds when the valves of all three are shut. Being connected together at the bottom, the water thus rises up through the material of the third bed and, as it does so, the surface sand to a depth of a few inches is agitated under water by means of a rake.

When a filter is first brought into use, the precipitation liquor sinks into the bed fairly rapidly; but after an hour or so, the finely divided matter which is caught in the first few inches of the sand renders the filtration more slow, and from that time the bed becomes completely ponded. The surfaces at the end of the day's work are usually covered with precipitation liquor to a depth of 9″.

Effluents.—Besides eleven chance samples, three sets of hourly samples of effluent, Nos. 3437, 3441 and 3445, were examined chemically. These were drawn on March 21st–24th, 1904, from 9.30 a.m. to 5.30 p.m. each day, from beds B and C, A and C, and A and B, respectively, and they are, therefore, comparable with series B of the hourly samples of precipitation liquor. They gave the following results :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(2·20 to 2·92)	2·58	(3)
Albuminoid Nitrogen	(0·14 to 0·17)	0·16	(3)
Total Organic Nitrogen	(0·30 to 0·65)	0·51	(3)
Oxidized Nitrogen	(1·04 to 1·61)	1·33	(3)
Total Nitrogen	(4·11 to 4.88)	4·41	(3)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(0·49 to 0·66)	0·57	(3)
,, ,, ,, ,, *in 4 hours*	(1·32 to 2·21)	1·86	(3)
Chlorine	(12·04 to 14·00)	13·17	(3)
Solids by Centrifuge (vols.)	(1·80 to 5·60)	4·10	(3)
Incubator test (Scudder)		3+	(3)
Incubator test (by smell)		2+, 1 (?)	(3)
Smell when drawn		1+, 2 (?)	(3)
Smell when analysed		3+	(3)

The above hourly samples of effluent were slightly opalescent, but remarkably free from suspended matter; they contained, in fact, little more than a trace. All of them had a clean smell on the day of analysis, and they may be taken, practically speaking, as having all withstood incubation. Two of them, however, were noted as having a doubtful smell when drawn. The first effluent of the three was distinctly the best, this being, no doubt, mainly due to the beds having had two days' rest previous to the sampling. The effluents may be described as fairly good, but the purifying process had not been carried quite to its full extent, probably because of the rapid rate of filtration of a concentrated liquid. Still, for a single treatment of a strong precipitation liquor, the purification effected is striking.

Compared with the 8-hourly samples of precipitation liquor, series B, to which those effluents correspond, we get the following reduction in figures :—

(The reduction, as compared with the 24-hourly samples of sewage, may also be given, but in this case it will appear rather greater than it really is, seeing that the 8-hourly samples of precipitation liquor were distinctly less strong than the 24-hourly samples of that liquor.)

Calculated on :—	Precipitation Liquor. 8-Hourly Samples. *Series* B.	Sewage. 24-Hourly Samples.
Total Nitrogen	35 per cent. reduction.	56 per cent. reduction.
Ammoniacal Nitrogen	47 „ „	63 „ „
Albuminoid Nitrogen	66 „ „	89 „ „
Total Organic Nitrogen	72 „ „	84 „ „
"Oxygen absorbed" *at once*	77 „ „	91 „ „
„ „ *in 4 hours*	82 „ „	93 „ „
Solids by Centrifuge (vols.)	96 „ „	99 „ „

Effluents,—Chance Samples.—Eleven chance samples of effluent were examined chemically, viz., Nos. 3130A, 3225B, 3226C, 3266, 3267, 3279A, 3280B, 3282, 3359, 3366 and 3386B.* Of these, Nos. 3225B and 3226C, 3266 and 3267, 3279A and 3280B were drawn from the same beds during the same periods of working, but after the liquor had stood on the beds for different lengths of time. They are therefore taken here as separate samples. With two exceptions the eleven were taken in the cooler months of the year, two of them in dry weather and the remainder in dry weather following wet. When the samples were taken the beds had been at work for different lengths of time, varying from about 20 minutes to 2 days.

They gave the following figures on analysis :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(0·12 to 3·96)	1·42	(11)
Albuminoid Nitrogen	(0·06 to 0·22)	0·10	(11)
Total Organic Nitrogen	(0·14 to 0·77)	0·54	(4)
Oxidized Nitrogen	(0·25 to 11·53)	3·00	(11)
Containing Nitrous Nitrogen	(0·0 to 0·36)	0·10	(11)
Total Nitrogen	(2·77 to 7·18)	4·06	(6)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(0·19 to 1·60)	0·50	(11)
„ „ „ „ *in 4 hours*	(0·61 to 3·20)	1·27	(11)
Dissolved Oxygen taken up in 24 hours (approx.)	(0·23 to 1·19)	0·69 ap.	(5)
Chlorine	(8·20 to 15·94)	11·24	(7)
Solids in Suspension	(1·80 and 1·16)	—	(2)
Solids by Centrifuge (vols.)	(Trace to 30·0)	9·2	(10)
Incubator Test (Scudder)		9+	(9)
Incubator Test (by smell)		10+, 1—	(11)
Smell when drawn		6+, 4−, 1 (?)	(11)
Smell when analysed		11+	(11)

The first of these effluents, No. 3130A—an effluent from strong liquor, drawn after the beds had been ponded for a long time—was slightly turbid and brown, but all the others may be described generally as opalescent and almost colourless. In only two cases did they contain any appreciable quantity of suspended solids, and then the amounts did not exceed about 2 parts per 100,000 (judging from the centrifuge figures). Six out of the eleven had a clean smell when drawn, while one was doubtful and four smelt more or less of sewage. On the other hand all the eleven, with the possible exception of No. 3,359, had a clean smell at the time of analysis and all of them but one withstood incubation. The quantity of dissolved oxygen taken up in 24 hours by five of the effluents averaged 0·69 part approximately. In every case but that of No. 3,130A there was a considerable quantity of nitrate present. With two exceptions, therefore (Nos. 3130A and 3359), it may be said that these effluents were of very fair quality, and even one of those two withstood incubation. The general figures of analysis confirm what has been already said with regard to the hourly samples, viz., that the percentage reduction of impurity effected by this system of single filtration is high, though the purification is not perhaps carried quite so far as it might be, over part of the time of working.

Compared with (*a*) the chance and (*b*) the 8-hours samples of precipitation liquor, the chance samples of effluent show the following reduction in figures; the corresponding reductions on the 24-hours samples of sewage may also be given, though, for the reasons stated, these are shown to be greater than they really are.

Calculated on :—	Precipitation Liquor.		Sewage.
	(*a*) Chance Samples.	(*b*) 8 Hours' Samples.	24 Hours' Samples.
Ammoniacal Nitrogen - - - - -	71 per cent.	71 per cent.	80 per cent. reduction.
Albuminoid Nitrogen - - - - -	81 ,,	85 ,,	93 ,, ,,
"Oxygen absorbed" *at once* - - - -	72 ,,	80 ,,	92 ,, ,,
,, ,, *in 4 hours* - - -	85 ,,	89 ,,	96 ,, ,,
Solids by Centrifuge (vols.) - - - -	83 ,,	92 ,,	98 ,, ,,

Bacteriological Notes.—Eight samples were examined bacteriologically. As regards the B. coli and neutral red broth tests, two samples yielded positive results with ·0001 c.c. (10,000 per c.c.); five samples with ·001 c.c. (1,000 per c.c.); and one sample with ·01 c.c. (100 per c.c.). In respect of the B. enteritidis sporogenes test, two samples yielded positive results with ·1 c.c. (10 per c.c.) and six samples positive results with 1 c.c. (1 per c.c.). It will thus be seen that the process effected a remarkable reduction in the number of bacteria of an intestinal type.

Description of the Samples.	Number of B. Coli (or gas-forming Coli-like microbes).	B.S. = Bile-salt glucose peptone test. N.R. = Neutral red broth test. I.N. = Indol test. L.P.M. = Lactose peptone milk test.	B. Enteritidis sporogenes test.	Remarks.
3279A Normanton filter effluent, 30/10/03.	1,000 not 10,000 (− indol) (+ clot)	1,000 not 10,000 N.R.	1 not 10	
3280B Normanton filter effluent, 30/10/03.	1,000 not 10,000 (+ indol) (+ clot)	1,000 not 10,000 N.R.	1 not 10	
3282 Normanton filter effluent, 31/10/03.	10,000 not 100,000 (− indol) (+ clot)	10,000 not 100,000 N.R.	1 not 10	
3366 Normanton filter effluent, 22/1/04.	100 not 1,000 (+ indol) (+ clot)	100 not 1,000 N.R.	10 not 100	
3386B Normanton filter effluent, 15/2/04.	1,000 not 10,000 (+ indol) (+ clot)	1,000 not 10,000 N.R.	10 not 100	

Description of the Samples.	Number of B. Coli (or gas-forming Coli-like microbes).	B.S. = Bile-salt glucose peptone test. N.R. = Neutral red broth test. I.N. = Indol test. L.P.M. = Lactose peptone milk test.	B. Enteritidis sporogenes test.	Remarks.
3437 Normanton filter effluent, 22/3/04.	1,000 not 10,000 (+ indol) (+ clot)	1,000 not 10,000 N.R.	1 not 10	
3441 Normanton filter effluent, 23/3/04.	1,000 not 10,000 (+ indol) (+ clot)	1,000 not 10,000 N.R.	1 not 10	
3445 Normanton filter effluent, 24/3/04.	10,000 not 100,000 (− indol) (+ clot)	10,000 not 100,000 N.R.	1 not 10	

Amount of Tank Liquor treated by the Filters.—The filters treat an almost constant quantity of tank liquor when they are at work. During the period of sewage flow gaugings in March, 1904, the amount of tank liquor going on to the filters was also measured, the measurement lasting three days. The following were found to be the quantities treated :—

March 21st - - - - - - - -	37,285 gallons.
March 22nd - - - - - - - -	38,855 ,,
March 23rd - - - - - - - -	40,810 ,,

The average daily amount, therefore, for the three days was 38,983 gallons. As the filters work only three days of $7\frac{1}{2}$ hours each a week, this is equivalent to an average of 17,143 gallons per day for the whole week.

On the assumption, therefore, that the filters work continuously day and night throughout the week, the following quantities are treated :—

Per square yard per 24 hours - - - - -	106·2 gallons.
Per cube yard per 24 hours - - - - -	98 ,,

When two filters are at work, however, and are receiving about 40,000 gallons in a day of $7\frac{1}{2}$ hours, the actual rate of filtration for the time being is much higher than this, being at the rate of 1,195 gallons per square yard per 24 hours, or 1,097 gallons per cube yard per 24 hours.

Experiments upon the Effect of Ponding a Bed.

In order to study the effects produced by ponding a bed for different lengths of time, a few experiments in this direction were carried out at Normanton. Three pairs of samples of effluent, Nos. 3225B and 3226C, 3266 and 3267, 3279A and 3280B, were drawn, each pair from the same bed during the same period of working, but after the bed had been in use for different lengths of time. Their figures of analysis are given in the following table :—

Parts per 100,000.	3225B. Drawn 15 minutes after starting the filters, which had been resting for two days.	3226C. Drawn after filters had been ponded for 40 minutes; *i.e.* drawn an hour later than No. 3225B.	3266. Drawn after beds had been sewaged for 2 hours.	3267. Drawn after beds had been ponded for $6\frac{3}{4}$ hours, *i.e.* 7 hours later than No. 3266.	3279A. Drawn after beds had been working for 2 hours.	3280B. Drawn after beds had been running for $25\frac{1}{2}$ hours, *i.e.* 24 hours later than No. 3279A.
Ammoniacal Nitrogen - - -	0·12	0·37	1·09	2·40	0·18	2·15
Albuminoid Nitrogen - - -	0·08	0·06	0·17	0·10	0·08	0·06
Oxidized Nitrogen - - -	11·53	4·94	3·20	1·38	5·86	0·83
"Oxygen absorbed" at 27°C *at once*	0·27	0·28	0·53	0·83	0·19	0·14
,, ,, ,, *in 4 hours*	0·90	0·85	1·65	1·74	0·61	0·72
Dissolved Oxygen taken up in 24 hours - - - - -					0·23	0·25ap.
Incubator test (Scudder) - -	+	+	+	+	+	+ practically.
Incubator test (by smell) - -	+	+	+	+	+	+
Solids in Suspension - - -	1·80	1·16				
Solids by Centrifuge (vols.)- -	30·0		8·0 ap.	1·8 ap.	7 2	4·8

The above figures show plainly the great accumulation of nitrate in beds which have rested, and they also show the gradual decrease in nitrate in the effluent as the beds stand ponded, although in no one of the foregoing cases was this reduction of nitrate carried to an extreme. Further, from the increased amounts of ammonia in the effluents drawn after long ponding, it is evident that the filtering material ceases to have the power of retaining ammonia after the oxidizing conditions have been weakened. This is, of course, merely an experimental demonstration of what has long been perfectly well known, viz., the necessity for working such filters as those at Normanton intermittently.

As bearing further on the above point, a few words may be added here with reference to two other pairs of chance samples of precipitation liquor and effluent, Nos. 3130 and 3130A, 3385A and 3386B. No. 3130A was the only effluent sample in which nitrate was markedly deficient in quantity, and in this case the bed had been ponded for about 8 hours with a *strong* liquor, before the sample of effluent was drawn. With precipitation liquor of the average strength of the chance samples examined, *i.e.*, with the less strong liquor, the method, including length of cycle of working followed at Normanton, produces satisfactory results; but when the liquor becomes concentrated (as in the case of No. 3130, which gave the figures:—Total Nitrogen, 8·5; "Oxygen absorbed" in 4 hours, 11·2), the purification, as exemplified in effluent No. 3130A, may be considerably affected. On the other hand, with a dilute wet-weather precipitation liquor, like No. 3385A (Albuminoid Nitrogen, 0·40; "Oxygen absorbed" in 4 hours, 5·75; Oxidized Nitrogen, 0·94), the period of ponding on the filters may evidently be prolonged much beyond the usual one of eight hours, and a satisfactory effluent still be produced (No. 3386B).

Effect of Temperature upon the Filters.—The observations upon temperature at Normanton have been made chiefly upon the occasion of each visit to the works; but they have also included measurements of temperature made every few hours throughout a period of three days, in March, 1904.

As no very severe weather prevailed at any time during the observations, it is not possible to make precise statements upon the question of how filters of this kind behave under such atmospheric conditions. It seems clear, however, from the chance observations made at each visit, that the temperature of the atmosphere in ordinary weather has only a slight effect upon the temperature of the effluent. Although several visits were paid purposely during frosty weather, the temperature of the effluent was never found to be lower than 6° C., and the greatest fall of temperature in the precipitation liquor during the process of filtration was not more than 1° C. (atmosphere 5° C., precipitation liquor 7° C., effluent 6° C.)

It is interesting to observe also that this effect was produced, not so much by a low temperature (atmosphere 5° C.) as by the strong cold wind blowing at the time.

LAND.

Only a small proportion of the total flow of precipitation liquor is treated on the filters. The rest is treated by intermittent downward filtration on an area of about 1¼ acres of land. As this part of the process did not come within the scope of our investigation, little attention has been paid to it, and no samples of the land effluent have been taken.

It may be observed, however, that the soil is not of a very suitable nature, though by opening up the drains and filling the trenches thus formed with ashes, and also by mixing ashes with the soil, it has been considerably lightened.

The precipitation liquor is distributed by means of grips cut in the soil, the effluent being collected below by 4″ and 6″ agricultural pipes, laid 12 feet apart, at an average depth of 3′ 6″. The two plots are used alternately. No crops are grown.

SUMMARY.

The dry-weather sewage at Normanton is very concentrated, and the night sewage is also much stronger than average night sewage, from the fact of Normanton having a large mining and railway population. A large quantity of subsoil water gains access to the sewers, but nevertheless the sewage treated at the works is a distinctly strong one. We are inclined to attribute its strength mainly to the fact that the water supply to the population is low, only 13 gallons per head. In character it is mainly a slop water sewage, and we think it may be taken as fairly typical of the sewage of towns of moderate size in the north of England.

There is no grit settlement, and the *whole* of the sewage (day and night) is run through the precipitation tanks. The precipitation effected is not good. This is not due to a rapid rate of flow through the tanks, but more probably to the small quantity of precipitant used (6·7 grains per gallon on the dry-weather flow), and also to the somewhat emulsified character of the liquid. The dry-weather precipitation liquor which the filters have to treat is strong, and, although the average liquor treated throughout the year is necessarily less concentrated, it is evidently but seldom that what might be called a weak liquor is run on to the filters. No difficulty is found in disposing of the sludge, but it dries very slowly in the lagoons into which it is pumped and gives rise to a nuisance there.

The filters are interesting as being an example of the International process of sewage treatment, still worked on its original lines; and especially also because the process involves the forcing of precipitation liquor through a fine-grained filter at a very rapid rate. As the results have shown, filtration by this system could not be made continuous, intermittence of feed being absolutely essential, both for mechanical and biological reasons.

When a filter at Normanton is freshly started after a rest, it is well stored with nitrate, and the surface of the filter, though of fine material, is in a sufficiently open condition to allow liquid to pass through it readily. The suspended and colloidal solids in the precipitation liquor, however, very soon begin to clog the surface, with the result that the filter ponds. Hence the conditions for aeration become gradually less favourable, while at the same time the accumulated nitrate in the filter is being used up or washed out. The process must thus, of necessity, be a discontinuous one, and indeed, in practice, the filtration would soon stop of itself, owing to the clogging. If, however, the filters are worked at a proper "rate of intermittence," they become good biological filters. They are used at Normanton for only 7½ hours a day on three days of the week.

The effluents examined were of very fair quality and showed a high degree of purification when compared with the precipitation liquor treated. They were exceptionally free from matter in suspension, only two samples out of fourteen containing any appreciable quantity. In every case but one there was considerable nitrate present, and out of fourteen samples tested (including three hourly sets), all but one withstood incubation. It is, however, to be noted that four of the eleven chance samples examined had more or less of a sewage smell when drawn, although by virtue of the dissolved oxygen and nitrate which they contained it had disappeared by the following morning. This would seem to indicate that the rapidity with which the filtration is carried out does not allow of the purification being quite effective over the whole eight hours, in the time that the liquid is actually passing through the filter. The oxidation of the organic matter of the precipitation liquor must be to a large extent due to accumulated nitrate in the beds. The figures of analysis, however, are sufficient to show that the quantity of still unpurified matter to which the sewage smell was due must have been small, in other words the effluents required very little further treatment to bring them up to a high standard of purity. The results obtained indicate that storage of the effluent for some hours after it had passed through the filters would have a beneficial effect upon it.

The brushing and upward-flow washing of the filters is easily carried out and does not involve much labour; the washings are run on to land. When the filters were constructed in 1885, their grading, from the top downwards, was 12″ sand, 12″ polarite, 3″ sand and 15″ pebbles. It was found, however, in 1897, *i.e.*, after twelve years' working, that the lower 3″ of sand had become clogged, and the filters were therefore reconstructed, with this portion of the sand left out. Since then they have remained quite clean, and up to now (1905) they show no signs of clogging. Thus, if carefully worked, filters constructed in this way may be made to last almost indefinitely.

Not infrequently considerable smell arises from the sludge as it dries in the lagoons, but otherwise the process may be said to be free from nuisance.

We should like, in concluding, to express our thanks to Mr. C. B. L. Fernandes, Clerk to the Normanton Urban District Council, and to Mr. J. Eaton, the Sanitary Inspector, for help in connection with our work at Normanton; we are specially indebted, also, to Mr. J. Fowler, the Manager of the Sewage Works.

OSWESTRY SEWAGE WORKS.

(Corporation of Oswestry.)

1. Situation of works - - - - -	About three quarters of a mile from the centre of the town.
2. Method of treatment - - - - -	Continuous flow settlement, followed by filtration on double contact beds.
3. Population draining to works during observations	9,800 (estimated average).
4. Water supply in gallons per head and whence obtained - - - - - - -	30 gallons; upland water from the hills N.W. of Oswestry—a fairly soft water.
5. Number of W.C.'s - - - - - -	2,140.
6. Sewerage system - - - - -	Combined.
7. Average dry weather flow in gallons per 24 hours	350,000.
8. Gallons of sewage per head per day - - -	35·7.
9. Character of the sewage - - - - -	A domestic and market town sewage of about average strength, containing waste liquors from breweries and tanneries.
10. Period of observations - - - - -	May, 1902 to January, 1905.
11. Age of contact beds - - - - -	4 years.
12. Amount of storm water treated on filters during observations - - - - - -	A little over twice the dry weather flow is treated.
13. Total capacity of tanks in gallons - - -	About 60,000.
14. Total area of filters in yards super. - - -	6,600.
15. Total cubic content of filter in yards cube -	9,900.
16. Nature of filtering medium - - - -	Cinders.
17. Gallons of sewage treated per yard super. per 24 hours (all filters included). - - -	66.
18. Gallons of sewage treated per yard cube per 24 hours (all figures included). - - -	51·37.
19. The final effluent is discharged into - - -	A ditch which joins the river Morda.

FLOW OF SEWAGE.

The sewerage of the district being upon the combined system, large quantities of storm water enter the sewers during wet weather. As the overflow situated close to the works on the main sewer is the only one on the system, the whole of this increased flow is brought to that point. There, however, everything over twice the dry weather flow is diverted direct to the ditch which receives the effluent from the filter beds.

The main sewer is capable of delivering sewage at the rate of something like 1½ million gallons per day. The greatest quantity treated per day during the observations was approximately 786,000 gallons.

The flow of sewage was gauged over a period of nine days, in May, 1902. On the first two of these days the flow was affected by three rather sharp showers (total rainfall 0·30 of an inch). As the ground was dry, however, the effect of this rain passed off rapidly, so that the gaugings during the six dry days which followed may probably be taken as representing approximately the dry weather flow.

The average daily flow during the dry days was approximately 350,000 gallons. This figure, therefore, has been taken as the dry weather flow.

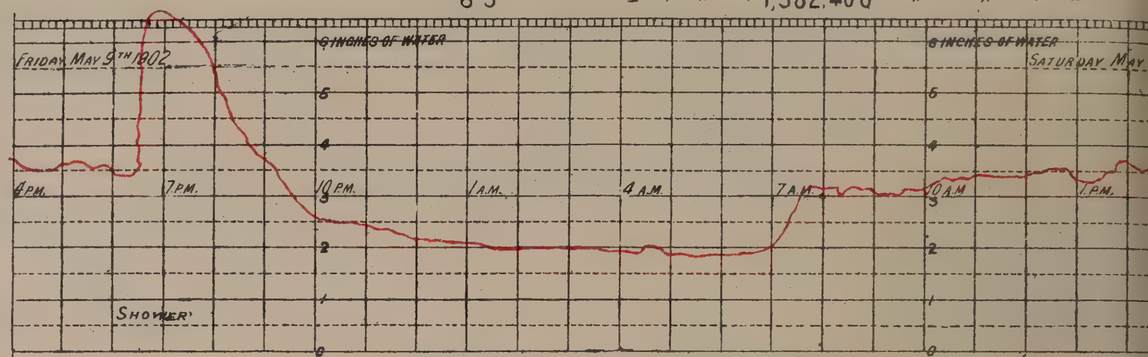
Diagram V.

Diagrams showing flow of Sewage at Oswestry as falling over a Weir 24" wide.

Note:- Over a Weir 24" wide

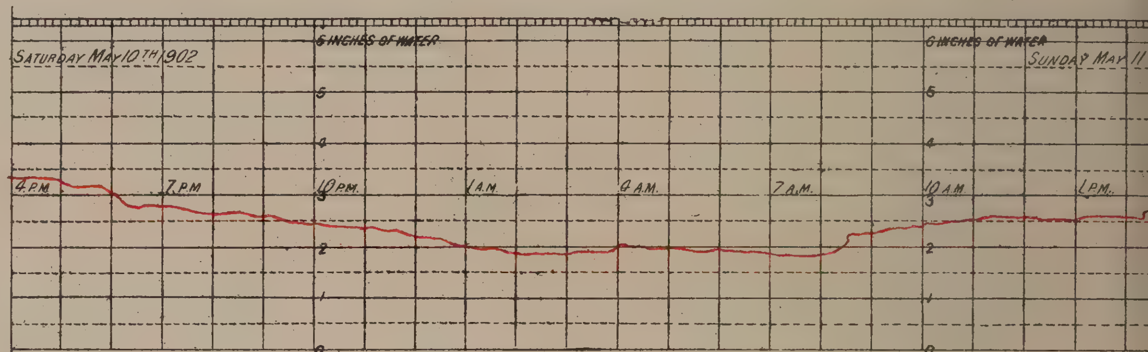
1·5	inches	=	a rate of 155,700 gallons per 24 hours.
2·0	"	=	" " " 240,300 " " " "
3·0	"	=	" " " 436,320 " " " "
4·0	"	=	" " " 671,040 " " " "
5·0	"	=	" " " 933,120 " " " "
6·0	"	=	" " " 1,226,880 " " " "
6·5	"	=	" " " 1,382,400 " " " "

HEAVY SHOWER. ON DRY GROUND. RAINFALL 0·15 INCH.



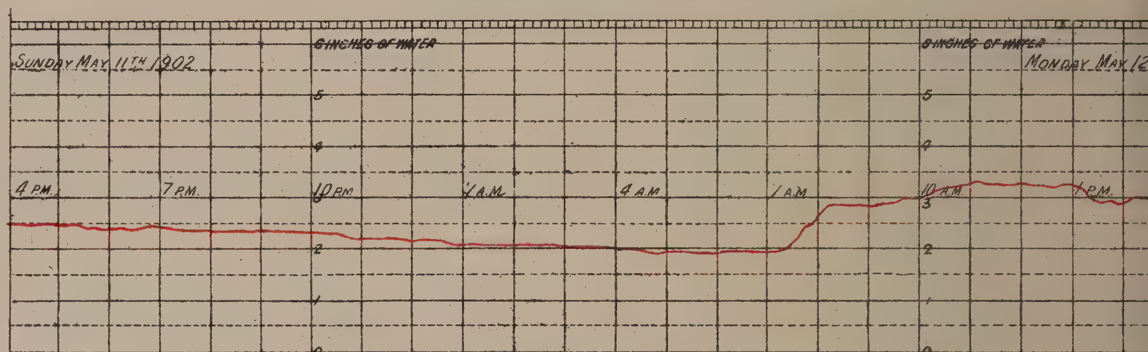
TOTAL FLOW FOR THE 24 HRS = 459,360 GALLONS

DRY DAY. RAINFALL NIL.



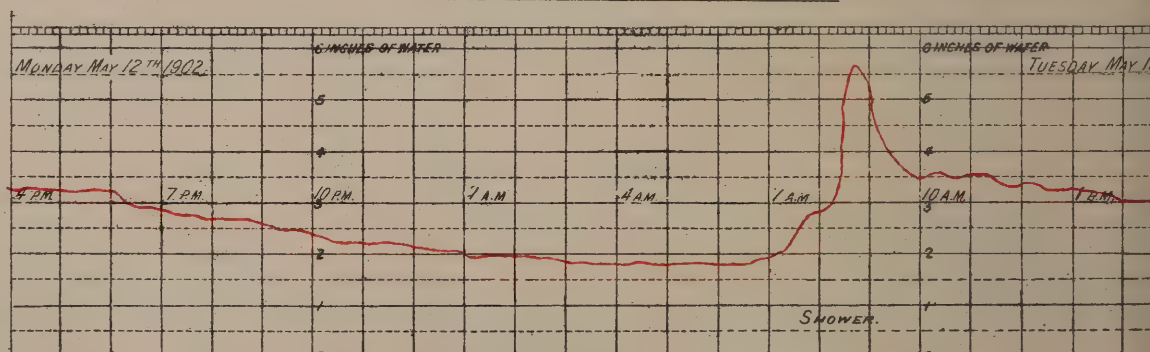
TOTAL FLOW FOR THE 24 HRS = 289,340 GALLONS

DRY DAY. RAINFALL NIL.



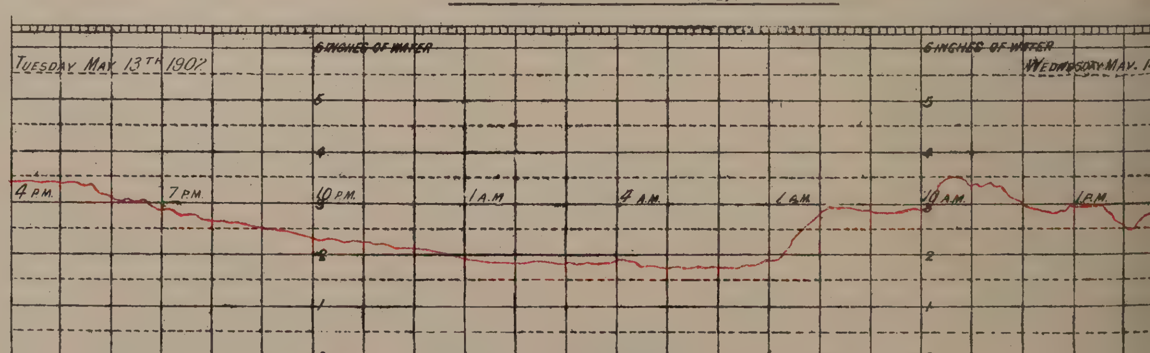
TOTAL FLOW FOR THE 24 HRS = 317,880 GALLONS

SHOWER ON DRY GROUND. RAINFALL 0·05 INCH.



TOTAL FLOW FOR THE 24 HRS = 362,670 GALLONS

DRY DAY. RAINFALL NIL.



TOTAL FLOW FOR THE 24 HRS = 322,330 GALLONS

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The flow in dry weather is of an even character, falling gradually from an average rate of something like 400,000 gallons per 24 hours, which continues from about 8 a.m. to 6 p.m., to a minimum rate of about 130,000 gallons per 24 hours, which is reached at about 2 a.m. and continues until 6 a.m.

The highest day's flow of 412,000 gallons occurred on the Wednesday of the week, which is market day, and the lowest day's flow of 289,000 gallons on the Saturday.

In wet weather, and especially during showers, the flow is subject to large and rapid variations. As the gauge was only up for a short time and then mostly in dry weather, we have only one record of a wet weather flow; but on that occasion two increases in the rate of flow in the proportion of 3 to 1 within ten minutes were recorded.

Subsoil Water.—In the wet season, a considerable quantity of water from the high-lying portion of the area enters the sewers, there being no other outlet for it. This being the case, it is reasonable to suppose that even after long continued dry weather the sewage is always mixed with a fair proportion of ground water, and the assumption is borne out by the fact that, during our dry weather gaugings in May, 1902, the night flow rate was never less than 130,000 gallons per 24 hours.

On Diagram V are given some illustrations of the sewage flow at Oswestry.

Crude Sewage.—Four sets of hourly samples, extending over one week, a sample of weak night sewage, and an ordinary chance sample were examined chemically, besides two samples of storm water. The hourly sets, Nos. 1, 3, 5 and 7, were drawn between May 8th and 15th, 1902, in varied weather, three heavy showers falling on the first two days. They may probably be regarded as approximating to the dry weather sewage. No. 1 represents a 24 hours' flow of sewage, and Nos. 3, 5, and 7 flows of 48 hours each, but every set is taken as one unit in working out the average; were No. 1 taken as half a unit, the average figures would work out a trifle higher than they do.

The following results were obtained:—

Parts per 100,000	Average.	Number of Estimations.	No. 3095, Weak Night Sewage, drawn Tues., Feb. 10th, 1903, 5 a.m.	No. 558, Ordinary Chance Sample, drawn Thurs., June 18th, 1903, 4.15 p.m.
Hourly Sets.				
Ammoniacal Nitrogen - (2·77 to 4·27)	3·53	(4)	4·61	
Albuminoid Nitrogen - - (0·67 to 1·20)	0·91	(4)	0·32	
Total Organic Nitrogen - (1·67 to 2·92)	2·25	(4)	1·12	
Oxidized Nitrogen - - (0·0 to 0·28)	Trace	(4)	0·75	
Total Nitrogen - - - (4·83 to 6·84)	5·85	(4)	6·48	
"Oxygen absorbed" at 27° C. *at once* - - - - (1·92 to 3·63)	2·92	(4)	4·33	5·74
"Oxygen absorbed" at 27° C. *in 4 hours* - - - (7·96 to 13·87)	11·27	(4)	5·76	23·80
Chlorine - - - - (6·78 to 11·44)	9·16	(4)	12·58	
Solids in suspension - - (21·30 to 35·60)	29·40	(4)		
Solids by centrifuge (vols.) (110·0 to 180·0)	143·0	(4)	7·0	300·0
Ratio of solids in suspension to centrifuge solids - (1 : 4·1 to 1 : 6·3)	1 : 5·0	(4)		
"Cellulose" (by alkali, acid and ether) - - - (4·04 to 6·16)	5·04	(4)		
Ratio of "cellulose" to solids in suspension - - (1 : 4·3 to 1 : 7·9)	1 : 6·0	(4)		
Incubator test (by smell) -			—	
Dissolved Oxygen taken up in 24 hours at laboratory temperature - - -			1·3 approx.	

The last two hourly sets were very similar in composition to one another, and were also stronger than the first two, the variations being partly due to rain and partly to the flushing of the cattle market on Wednesday evening and Thursday morning. Taken all over, the dry weather sewage may be described as one of about average strength.

The sample of night sewage, No. 3095, drawn at 5 a.m. in the month of February, was very strong ammoniacally, and also contained an exceptionally large quantity of chlorides. We are unable to account for the latter. It was, however, an almost clear and colourless liquid, and showed on analysis nearly a part of oxidized nitrogen—a sign of subsoil water in the sewers.

The remaining chance sample, No. 558, drawn on a Thursday afternoon in June, contained cattle market refuse. It was twice as strong as the average of the hourly samples, both as regards "oxygen absorbed" from permanganate and suspended solids. The sewage thus varies very considerably in strength at different times of the day and week.

The figures of analysis may also be given here for the two chance samples of storm water sewage examined. No. 510 was drawn on Monday, March 30th, 1903, at 4.15 p.m., after the overflow had been in action for about two hours; when No. 3,264A was drawn, on Thursday, October 15th, 1903, at 11.30 a.m., the overflow had been working for about twenty-six hours. They gave the following results:—

Parts per 100,000.	No. 510.	No. 3264A.
Ammoniacal Nitrogen	1·24 ap.	0·94
Albuminoid Nitrogen	—	0·87
Oxidized Nitrogen	—	0·36 ap
Total Nitrogen	3·05	—
Oxygen absorbed at 27° C. (80° F.) *at once*	2·43	1·70
" " " " *in 4 hours*	13·06	8·24
Solids in suspension	86·50	5·90
Solids by centrifuge (vols.)	186·0	77·0
Ratio of solids in suspension to centrifuge solids	1 : 2·2	1 : 13·1
Incubator test (by smell)	Failed	Failed

No. 510 had a sour smell when analysed and contained as much as 86 parts of suspended solids, of which 66 parts were mineral matter; while No. 3264A was red in colour with blood from slaughter houses, and had a soapy smell. The desirability of settling and purifying such liquids as these is obvious.

Bacteriological Notes.—Six samples of crude sewage were examined bacteriologically, The results are considered under "settled sewage" in a later part of the Report.

SETTLING TANKS.

Number	2.
Size of each	70 feet by 15 feet (approximately).
Depth	4 feet 6 inches.
Capacity of each	About 30,000 gallons.
Total Capacity	About 60,000 gallons.

Construction.—Brick and cement walls with concrete bottoms. The sewage enters each tank through a single pipe connecting to the main sewer; having flowed over a baffle wall, situated close to the inlet end, and through the tank, it issues again through a single outlet valve placed rather below the level of the liquid at the outlet end.

Working.—The tanks are used in parallel for the treatment of the whole of the sewage up to twice the dry-weather flow. During the cleaning of one tank the whole of the sewage is passed through the other.

Flow Through.—With a dry-weather flow of 350,000 gallons per 24 hours, the flow through the tanks would be once in 4·1 hours, at the rate of 3·4 inches per minute.

Sludging.—The settling tanks are cleaned out every four or five weeks in the following manner:—

The supernatant liquid having been run off, the sludge is raised up by means of a chain-pump and delivered into a hopper, into which a supply of fine cinders is also directed. The mixture of sludge and cinders is then lifted by an elevator and delivered into small trucks for removal. The machinery is driven by steam power.

The matter deposited in the trucks is therefore a semi-solid mixture of sludge and cinders. This is tipped upon the works and, having dried sufficiently to be spadeable, is sold to farmers at the price of 6d. per load. At one time 1s. 6d. per load could be obtained for it, but the price has gradually fallen.

Settled Sewage.—Four sets of hourly samples and four chance samples were examined chemically. The hourly sets, Nos. 2, 4, 6, and 8, were drawn at the same time and under the same conditions as the hourly samples of crude sewage. They gave the following figures:—

	Parts per 100,000.	Average.	Number of Estimations.
Hourly Sets.			
Ammoniacal Nitrogen	(3·25 to 3·56)	3·48	(4)
Albuminoid Nitrogen	(0·79 to 1·15)	0·92	(4)
Total Organic Nitrogen	(1·41 to 2·16)	1·84	(4)
Oxidized Nitrogen	(0·0 to 0·2 approx.)	Trace.	(4)
Total Nitrogen	(5·34 to 5·86)	5·62	(4)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(2·09 to 2·73)	2·42	(4)
" " " " *in 4 hours*	(9·19 to 12·59)	10·37	(4)
Chlorine	(8·02 to 11·18)	8·90	(4)
Solids in suspension	(13·70 to 32·60)	22·80	(4)
Solids by centrifuge (vols.)	(83·0 to 183·0)	132·0	(4)
Ratio of solids in suspension to centrifuge solids	(1 : 4·7 to 1 : 6·8)	1 : 5·9	(4)
"Cellulose" (by alkali, acid, and ether)	(2·28 to 6·00)	3·73	(4)
Ratio of "cellulose" to solids in suspension	(1 : 4·5 to 1 : 8·9)	1 : 6·4	(4)

During the week when the above hourly sets of settled sewage were drawn, the length of time given for settlement was only about 4 hours. Comparing these average figures of analysis with those given by the hourly samples of crude sewage, we get the following reduction:—

Calculated on :—	Reduction.
Total Nitrogen	4 per cent.
Albuminoid Nitrogen	+1 "
Total Organic Nitrogen	18 "
"Oxygen absorbed" *at once*	17 "
" " *in 4 hours*	8 "
Solids in suspension	22 "
Solids by centrifuge (vols.)	8 "

The settlement was thus, *on the average*, very inadequate. It had only removed about one-fifth part of the suspended matter from the crude sewage, leaving an average of 22 parts in the liquid to be treated on the filters. It should be noted, however, that in the first of the four pairs of hourly sets of crude and settled sewage, the settled shows the higher figure for suspended solids, this being no doubt due to the three showers which fell during those two days (=0·30 inch rainfall), and to the consequent more rapid rate of flow through the tanks at certain hours. In other respects this liquid may be described as of average sewage strength.

The suspended solids in the eight samples were respectively:—

Parts per 100,000.	Crude Sewage.	Settled Sewage.
First Sets	21·3	26·8
Second „	32·0	32·6
Third „	28·4	13·7
Fourth „	35·6	18·0

In dry weather, therefore, the reduction in the suspended solids was about 50 per cent.

Chance Samples.—The four chance samples of settled sewage examined chemically, Nos. 3096A, 559, 3290 and 3390, were drawn—the first two in dry weather, in the months of February and June, and the second two in wet or shortly after wet weather, in the months of November and February. They therefore varied very much in composition, the first pair being two to three times as strong, organically, as the others.

The following figures were obtained on analysis:—

Parts per 100,000.		Average.	Number of Estimations.
Total Nitrogen	(2·94 to 7·80)	5·25	(4)
"Oxygen absorbed" at 27° C. (80° F., *at once*	(1·35 to 5·72)	3·48	(4)
„ „ „ *in 4 hours*	(4·32 to 23·02)	12·17	(4)
Solids in suspension	(9·40 to 25·50)	15·09	(4)
Solids by centrifuge (vols.)	(40·0 to 140·0)	80·0	(4)
Ratio of solids in suspension to centrifuge solids	1 : 4·3 to 1 : 5·5	1 : 5·2	(4)

No. 3096B was noted as having an odour of hippuric acid when analysed. When No. 3390 was drawn (a very dilute sample containing approximately 0·5 part of nitric nitrogen and 9·4 parts of suspended solids, and giving the figure 4·32 for "oxygen absorbed" in 4 hours), the flow through the tanks was so increased by the wet weather that the greater part of the settled sewage was being run into the ditch.

With only four chance samples, there would be no object in attempting any comparison with the hourly ones, excepting to point out that, *on the average*, the composition of both was very similar, though the chance samples had somewhat less suspended matter.

Bacteriological Notes.—Six samples of crude, five samples of settled, and two samples of overflow sewage were examined bacteriologically. The results are grouped together in the following table. Practically all the samples yielded positive results with the B. coli test and presumptive tests for B. coli with $\frac{1}{100,000}$ c.c. (100,000 per c.c.); and positive results with the B. enteritidis sporogenes test with $\frac{1}{100}$ to $\frac{1}{1000}$ c.c. (100 to 1,000 per c.c.).

Description of the Sample.	Number of B. coli (or gas-forming coli-like microbes).	B.S. = Bile salt glucose peptone test. N.R. = Neutral red broth test. In. = Indol test. L.P.M. = Lactose peptone milk test.	B Enteritidis sporogenes test.	Remarks.
1. Oswestry crude sewage. 9/5/02.	100,000 (— indol) (— clot)	100,000 B.S. 100,000 N.R. 100,000 In. 100,000 L.P.M.	100 not 1,000	"Gas" test + ·001 cc. (24 hours at 20° C.)
3. Oswestry crude sewage. 11/5/02.	100,000 (— indol) (+ clot)	1,000 not 10,000 B.S. 10,000 not 100,000 N.R. 100,000 In. 10,000 not 100,000 L.P.M.	10 not 100	"Gas" test + ·001 cc. (24 hours at 20° C.)
5. Oswestry crude sewage. 13/5/02.	100,000 (— indol) (+ clot)	100,000 B.S. 100,000 N.R. 100,000 In. 100,000 L.P.M.	100 not 1,000	"Gas" test + ·001 cc. (24 hours at 20° C.)
7. Oswestry crude sewage. 15/5/02.	100,000 (+ indol) (+ clot)	100,000 B.S. 100,000 N.R. 100,000 In. 100,000 L.P.M.	1,000 not 10,000	"Gas" test + ·001 cc. (24 hours at 20° C.)
3095. Oswestry crude sewage. 10/2/03.	—	10,000 not 100,000 N.R. 100,000 L.P.M.	100 not 1,000	
558. Oswestry crude sewage. 18/6/03.	—	100,000 N.R.	at least 100	
2. Oswestry settled sewage. 9/5/02.	100,000 (+ indol) (+ clot)	100,000 B.S. 100,000 N.R. 100,000 In. 100,000 L.P.M.	1,000 not 10,000	"Gas" test + ·001 cc. (24 hours at 20° C.)
4. Oswestry settled sewage. 13/2/02.	100,000 (+ indol) (+ clot)	100,000 B.S. 100,000 N.R. 100,000 In. 100,000 L.P.M.	1,000 not 10,000	"Gas" test + ·001 cc. (24 hours at 20° C.)
6. Oswestry settled sewage. 15/5/02.	100,000 (+ indol) (+ clot)	100,000 B.S. 100,000 N.R. 100,000 In. 100,000 L.P.M.	100 not 1,000	"Gas" test + ·001 cc. (24 hours at 20° C.)
3096A. Oswestry settled sewage. 10/2/03.	—	100,000 N.R. 100,000 L.P.M.	1,000 not 10000	
559. Oswestry settled sewage. 18/6/03.	—	100,000 N.R.	1,000 not 10,000	
510. Oswestry storm overflow. 30/3/03.	—	100,000 N.R.	100 not 1,000	
3264A. Oswestry storm overflow. 15/10/03.	100,000 (+ indol) (+ clot)	100,000 N.R.	100 not 1,000	

PRIMARY CONTACT BEDS

Number - -	9.
Size of each - - - -	60 feet by 60 feet at surface; 51 feet 6 inches by 51 feet 6 inches at bottom.
Superficial area of each - -	400 square yards.
Total area - - - -	3,600 square yards.
Depth of Material - - -	4 feet 6 inches.
Cubic content of each - -	518 cube yards.
Total cubic content - -	4,662 cube yards.
Material - - - -	Cinders from old house refuse, ranging from ½ inch to 1½ inch in diameter.

Construction.—Excavation in stiff soil and earth banks. The earth banks are clay puddled where necessary.

Distribution.—One main wooden trough, connecting to two branch troughs on either side.

Underdraining.—Three-inch agricultural pipes, laid two feet apart, connecting to three main channels, all constructed of brick on edge and cover; one of these channels is laid down the centre of the bed, while the two others are laid diagonally. All three main channels deliver to the outlet chamber containing the discharge valve.

Working.—The primary beds are worked in simple rotation, eight filters constituting the working set. One filter is therefore always resting and, as a fresh filter is cut out of the working set each week, every filter receives one week's rest in nine. At the end of its rest it is carefully raked and dug over.

Originally the primary beds were filled and emptied automatically by means of a gear designed by Mr. Wynne Roberts, the late Surveyor, but as this was found to be unreliable, filling and emptying by hand was resorted to. The latter method was in use during the whole of our observations.

At the commencement of their life the primary beds received about two fillings per day, and gave a contact of two hours. In 1902 the number of fillings per day had increased to something like five, while the period of contact had diminished to about forty five minutes, and this rate of working continued almost throughout the observations, excepting in very dry weather.

Age of Beds.—All the primary beds were constructed and brought into use between the spring of 1898 and the summer of 1899. Bed No. 9 was renewed in August, 1902, bed No. 8 in July, 1903, and bed No. 1 in February, 1905.

Capacity.—The original empty tank capacity of the nine primary beds was 785,453 gallons, and, assuming that the material occupied two-fifths* of the filter tank space when first put in, the original total water capacity was 314,182 gallons. Although of equal size, the primary beds at Oswestry were brought into use at different times, and as we have not been able to keep capacity records of all the nine beds, it has been thought inadvisable to apply the results obtained from the gaugings of three beds (Nos. 1, 2, and 7) to the whole area. The three beds, however, were carefully selected as being typical of the whole, and we think it may be inferred that their capacities are a fair index of the capacities of all the primary beds. Nos. 1 and 2 were brought into use in the summer of 1898, and No. 7 in the summer of 1899.

At the time of the first gauging, therefore, in May, 1902, beds No. 1 and 2 were four years old, while No. 7 was about 3 years old. The original empty tank capacity of each was 87,272 gallons, and, on the assumption that the material, when new, occupied two-fifths of the filter tank space, the original water capacity of each bed was 34,909 gallons. The first gauging was made in May, 1902, when the capacities were found to be as follows:—

No. 1, bed - - - -	7,355	gallons.
No. 2, bed - - - -	7,156	,,
No. 7, bed - - - -	8,773	,,

Bed No. 7, therefore, retained at that date 25·1 per cent. of its original water capacity, and beds Nos. 1 and 2, 21·1 per cent. and 20·5 per cent. respectively.

We understand that in the summer of 1899, when all the primary beds were for the first time in use, they received an average of not more than two fillings per day. At the time of the first gauging (May, 1902), they were receiving on an average four or five fillings per day, owing to the serious loss of capacity which had taken place in the interval. All the filters had then a rather clogged appearance, the material being so saturated with sewage solids as to allow one's foot to sink some distance into it, if any attempt were made to walk upon a bed. On the other hand, the material was by no means impervious, the settled sewage entering and leaving the beds quite freely.

It was obvious that at this time some of the filters, and especially the older ones, were in a serious state and required renovation. We thought, however, that their continued use in this condition might afford useful evidence upon two points—(1) how far the loss of capacity would eventually go, and (2) whether the clogging would ultimately extend to the secondary beds also. We therefore obtained permission for the three typical beds to continue in use without renewal.

*As a rule we have assumed that filtering material, when first put in, occupies one half the space of the filter tank. In the case of Oswestry, however, the gauging of a refilled bed (No. 1) by Mr. Lacey showed a water-holding capacity of only about two-fifths. We have therefore taken this figure in making our estimate of the original water capacity of all the beds. The difference is no doubt due to the nature of the material used at Oswestry.

From May 13th, 1902, to February 10th, 1903, the beds received an average of 4·9 fillings per day. At the end of this time the capacities were again measured, with the following results:—

No. 1 bed	- - - -	5,598 gallons.
No. 2 bed	- - - -	6,583 „
No. 7 bed	- - - -	9,294 „

The capacities of Nos. 1 and 2, therefore, had still further diminished, but that of No. 7, owing to a week's rest just previous to the gauging, had slightly increased. The percentage capacities were:—

No. 1 bed	-	16 per cent. of its original water capacity.
No. 2 bed	-	18·9 „ „ „
No. 7 bed	-	26·6 „ „ „

From this time no further gaugings were made until almost the end of the observations, in January, 1905, each bed receiving on an average 4·85 fillings per day during the interval (24 months).

On January 30th, 1905, the capacities were:—

No. 1 bed	- - - -	3,447 gallons.
No. 2 bed	- - - -	3,660 „
No. 7 bed	- - - -	4,179 „

and the percentage capacities:—

No. 1 bed	-	9·9 per cent. of its original water capacity.
No. 2 bed	-	10·5 „ „ „
No. 7 bed	-	12·0 „ „ „

All three beds were now in a very sodden condition.

To the primary beds, constructed and used as they were, we should assign an economical "life" of about three or, at the most, four years, for it will be noted that they were worked very hard and were called upon to treat a large quantity of suspended matter, owing to the poor settlement effected by the tanks.

Primary Effluents.—Four chance samples were examined chemically, viz., Nos. 3096B, 3263, 3289 and 3389. Only the first of these was drawn in dry weather, in February, 1903, all the others being wet weather samples, taken in the months of October, November and February; they were all taken at mid-flow, and the periods of contact were respectively, $1\frac{1}{2}$, 1, $\frac{2}{3}$, and $\frac{1}{2}$ hour.

The following figures were obtained:—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - - - -	(0·50 and 0·47)		(2)
Albuminoid Nitrogen - - - - - - -	(0·18 and 0·22)		(2)
Total Organic Nitrogen - - - - - - -	(0·73)		(1)
Oxidized Nitrogen - - - - - -	(0·26 ap. to 0·66)	0·51 ap.	(4)
Total Nitrogen - - - - - - - - -	(1·82 to 3·71)	2·46	(3)
"Oxygen absorbed" at 27° C. (80° F.) *at once* - - -	(0·50 to 1·75)	0·89	(4)
„ „ „ „ *in 4 hours* - -	(1·95 to 3·95)	2·93	(4)
Dissolved Oxygen taken up in 24 hours at about 18°C.	(0·86ap. and 2·62)		(2)
Incubator test (Scudder) - - - - - - - - - - -		3 passed. 1 failed.	(4)
Incubator test (by smell) - - - - - - - - - - -		1 passed. 3 failed.	(4)
Smell when drawn - - - - - - - - - - -		1 good. 2 bad.	(3)
Smell when analysed - - - - - - - - - - -		4 good.	(4)
Chlorine - - - - - - - - - -	(3·52 and 4·30)		(2)
Solids in suspension - - - - - - - - -	(6·30)		(1)
Solids by centrifuge (vols) - - - - - - -	(18·0 to 52·0)	39·0	(4)
Ratio of solids in suspension to centrifuge solids - -	(1: 8·3)		(1)

In appearance the above chance samples of primary effluent were rather turbid and of a brownish tinge, and they contained considerable quantities of suspended matter (probably not less than an average of 5 parts per 100,000, judging from the centrifuge figures). All of them had a clean smell on the day of analysis, but only one was able to withstand incubation. The oxidized nitrogen averaged about 0·5 part per 100,000, while the 4 hours' "oxygen absorbed" figure was 2·93. For primary effluents, therefore, these showed a good purification. Since three of the four were dilute wet-weather samples, the advisability of contrasting them with the hourly samples of settled sewage seems doubtful, but, subject to this proviso, they show the following reduction in figures :—

Calculated on :—	Reduction.
Total Nitrogen	56 per cent.
"Oxygen absorbed" *at once*	63 ,, ,,
"Oxygen absorbed" *in 4 hours*	72 ,, ,,
Solids by Centrifuge (vols.)	70 ,, ,,

The first three of these reduction figures are no doubt better than would be given by the average of a large number of samples, representing weather of every kind.

Bacteriological Notes.—Three samples of primary bed effluent were examined bacteriologically. They yielded positive results with the B. coli test and presumptive tests for B. coli with 1/10,000 c.c. (10,000 per c.c.), and positive results with the B. enteritidis sporogenes test with 1/100 c.c. (100 per c.c.).

Description of the Sample.	Number of B. Coli (or gas-forming Coli-like microbes).	B.S. = Bile-salt glucose peptone test. N.R. = Neutral red broth test. In. = Indol test. L.P.M. = Lactose peptone milk test.	B. Enteritidis sporogenes test.	Remarks.
3096B. Oswestry primary bed effluent, 10/2/03.	—	100,000 N.R. 10,000 not 100,000 L.P.M.	100 not 1,000	
3289. Oswestry primary bed effluent, 4/11/03.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R.	100 not 1,000	
3389. Oswestry primary bed effluent, 16/2/02.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R.	100 not 1,000	

SECONDARY CONTACT BEDS.

Number - - - - -	9.
Size of each - - - - -	60 feet by 50 feet at surface; 51 feet 6 inches by 41 feet 6 inches at bottom.
Superficial area of each - - -	333 square yards.
Total superficial area - - -	3,000 square yards.
Depth of material - - - -	4 feet 6 inches.
Cubic content of each - - -	425 cube yards.
Total cubic content - - -	3,825 cube yards.

Secondary Contact Beds.—continued.

Material - - - - - -	House ashes ranging from $\frac{3}{8}$ inch to $1\frac{1}{2}$ inch in diameter.
Construction - - - - - -	Excavation in stiff soil, with earth banks.
Distribution - - - - - -	One main wooden trough laid down the centre of each bed, connecting to two branch troughs on either side.

Underdraining.—Three-inch agricultural pipes, laid two feet apart, connecting to three main channels, all constructed of brick on edge and cover; one of these channels is laid down the centre of the bed, while the two others are laid diagonally. All three main channels deliver to the outlet chamber containing the discharge valve.

Age of Beds.—The secondary beds were brought into use as they were finished, from the spring of 1898 to the summer of 1899.

Working.—Excepting that one bed is always kept in reserve for the purpose of resting, the secondary beds are worked in simple rotation. They were originally filled and emptied automatically, by means of a gear designed by Mr. Wynne Roberts; but as this was found to need constant attention, the valves are now for the most part actuated by hand.

The number of fillings given to the beds increased gradually during the observations. In 1902 it averaged 2·4 fillings of primary bed effluent per day for each bed; while in 1905, at the end of the observations, it had increased to an average of 3·2 fillings.

The unusual feature in the working of the Oswestry secondary beds is that during the night and the early hours of the morning they are used for the treatment of the dilute crude sewage which then reaches the works. This plan was commenced in February, 1903, its object being to relieve the primary beds. From February 28th, 1903, therefore, to the end of the observations in January, 1905, the secondary beds received an average of 0·6 filling per day of crude night sewage.*

For the whole period of the observations, and including all fillings, whether of primary bed effluent or of crude night sewage, the average number of fillings per day given to the secondary beds was 3·0.

One secondary bed is cut out of the working set each week for the purpose of resting it, so that each bed receives one week's rest in nine. At the end of its week's rest it is forked over to a depth of nine inches or a foot.

Capacity.—Owing to the small size of the feed channels and also to the automatic gear, it was found almost impossible to form any approximate estimate of the capacity of the secondary beds by actual gaugings, and the idea of doing so had therefore to be given up. But the steady increase in the number of fillings given to each bed per day, and the change in appearance of the surface material throughout the observations, showed that a gradual but marked loss of capacity had taken place.

The number of contacts given to each bed per day increased from 2·4 at the commencement of the observations, in May, 1902, to an average of 3·2 during 1904, while the surface material changed from a clean to a clogged and spongy condition. That the continued use of the clogged primary beds was the cause of this there can be no doubt, for the primary bed effluent naturally deteriorated, especially in regard to suspended solids, as those beds clogged and gave shorter and shorter periods of contact.

The Borough Surveyor considers that the secondary beds will require to be either washed or renewed in 1906. On this estimate, their "life," as they are worked at Oswestry, may be said to be something like seven or eight years.

* The treatment of night sewage upon the secondary beds has now been discontinued.

Secondary Effluents.—Besides four special samples, to be spoken of later, ten ordinary chance samples of secondary contact bed effluent were examined chemically, these including one sample of "works" effluent. Their numbers were **3097, 509, 560, 3181, 3245, 3264, 3288, 3387, 3526** and **3615**, and they were drawn at mid-flow at practically all seasons of the year between February, **1903**, and January, **1905**, but the cool weather samples constituted about two-thirds of the whole. Four of them were taken in dry weather and six in wet or immediately after wet weather. Eight of the samples had **2** hours' secondary contact each, and the remaining two had **1** to **1½** hours. Taken altogether, they may be considered as fairly representative of the working at Oswestry.

The following results were obtained:—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(0·03 to 0·64)	0·56	(8)
Albuminoid Nitrogen	(0·05 to 0·34)	0·18	(7)
Total Organic Nitrogen	(0·38 to 0·73)	0·58	(4)
Oxidized Nitrogen	(0·20 to 3·22)	1·16	(9)
Including Nitrous Nitrogen	(0·0 to 0·40)	0·09	(10)
Total Nitrogen	(1·39 to 4·30)	2·59	(5)
Oxygen absorbed at 27° C. (80° F.) *at once*	(0·09 to 1·11)	0·55	(10)
" " " *in 4 hours*	(0·67 to 2·84)	1·76	(10)
Dissolved Oxygen taken up from water in 24 hours at 18°C.	(0·08 to 2·08 ap.)	0·72 ap.	(6)
Incubator Test (Scudder)		6 passed 1 failed	(7)
" " (by smell)		7 or 8 passed 2 failed	(10)
Smell when drawn		6 good 2 doubtful 2 bad	(10)
Smell when analysed		10 good.	(10)
Chlorine	(3·96 to 11·50)	7·01	(6)
Solids in suspension	(4·60)		(1)
Solids by centrifuge (vols.)	(trace to 46·0)	20·5	(9)
c.c. per Litre.			
Oxygen in solution when analysed	(0·0 to 2·1)	1·1	(4)

In appearance the secondary effluents were usually slightly turbid or opalescent and of a brownish tint, and the greater part of them were very free from suspended matter; judging from the centrifuge figures, the latter averaged something like **2** parts per **100,000**. Six of the samples were noted as having a clean smell when drawn, while all of them had a clean smell when analysed. With two exceptions they were all relatively well nitrated, while seven, or more probably eight, of the ten withstood the incubator test. The amount of dissolved oxygen taken up from solution by the **6** samples tested for it varied very much; the average figure was somewhat high; but, on the other hand, some of the samples took up very little.

It is thus evident that these secondary effluents were not uniform as regards purification, but the greater number of them may be taken as of fair quality; it would not have required much further purification to have made them satisfactory from a chemical point of view. It must be borne in mind that these effluents were produced under unfavourable conditions, owing to the already clogged primary beds being kept at work, at our request, for a much longer period than they would have been in the ordinary course. During the greater part of the observations, the length of contact given in the primary beds was only ½ to 1 hour. Had the primary beds been renewed, so as to allow of a 2 hours' contact, we think that, in spite of the poor settlement given to the sewage in the settling tanks, the final effluent would undoubtedly have been much more uniform as regards purification. No true dividing line, as regards quality, can be drawn here between dry and wet weather effluents.

Compared with the hourly samples of crude and of settled sewage, these effluents show the following reduction in figures:—

Calculated on :—	Compared with— Crude Sewage.	Settled Sewage.	Number of Estimations.
Total Nitrogen - - - - - - -	56 per cent. reduction	54 per cent.	(5)
Ammoniacal Nitrogen - - - - - -	84 ,, ,,	84 ,,	(8)
Albuminoid Nitrogen - - - - - -	80 ,, ,,	80 ,,	(7)
"Oxygen absorbed" *at once* - - - - -	81 ,, ,,	77 ,,	(10)
,, ,, *in 4 hours* - - - -	84 ,, ,,	83 ,,	(10)
Solids by centrifuge (vols.) - - - - -	86* ,, ,,	84* ,,	(9)

A few words may be added with regard to special points in some of the secondary effluents examined (Nos. 509, 3,264, and 3,526 have already been included in the eleven chance samples just discussed).

No. 509 was a sample with the usual two hours' contact, but it represented the first filling of a bed after the latter had had a week's rest. This sample, as might have been expected, showed a large quantity (fully 3 parts) of oxidized nitrogen, but at the same time contained 0·73 part of organic nitrogen, and it took up more than 2 parts of dissolved oxygen from solution in 24 hours. While, therefore, it had dissolved out much accummulated nitrate from the bed, the organic impurity present was by no means well oxidized. There was comparatively little suspended matter present.

No. 3,264 was a very good sample of what may be taken as the average "works" effluent from a dilute sewage. It took up practically no oxygen from solution in 24 hours, and the other figures of analysis were correspondingly good.

In No. 3,526, a sample containing 4·6 parts of suspended matter, there was little oxidized nitrogen, and the sample failed to withstand incubation; yet the quantity of dissolved oxygen which it took up from water in 24 hours was not excessive (0·67 part).

No. 3,244 represented a "first flush," *i.e.*, a sample from the first five minutes' emptying of a bed giving 2 hours' contact to a dilute sewage. It had an inoffensive smell when

* These figures are probably too low, as regards a comparison by weight.

drawn, but contained practically no nitrate and failed to withstand incubation. The mid-flow sample of the same emptying, No. 3,245, contained rather more nitrate and less solids, and withstood incubation.

No. 3,388 was a sample of *drainings*, after one hour's secondary contact of a dilute sewage. It was relatively very well nitrated, but took up 0·73 part of dissolved oxygen in 24 hours, showing that it still contained an appreciable quantity of oxidizable matter.

No. 3,527 represented a sample of effluent from $3\frac{1}{2}$ hours' single contact of crude sewage of (inferentially) moderate strength, on one of the secondary beds. It was a fairly good sample, though with 4 parts of suspended solids.

No. 3616 is also to be differentiated from the average of the secondary effluents. It was drawn on Monday, January 30th, 1905, at 4 p.m., in dry weather, under most disadvantageous conditions as regards working, thus:—(1) when the corresponding settled sewage went on to the primary beds, only one tank was in use, the other being in process of sludging; (2) the sewage, which was strong, received only 30 minutes' contact on the primary bed; and (3) the secondary bed had treated crude night sewage at the previous filling. The effect of these accumulated adverse conditions was seen in the very poor quality of the effluent, which—out of a total of 3·34 parts of nitrogen—contained 0·62 part of albuminoid and no oxidized nitrogen on the following day. The 4 hours' "oxygen absorbed" figure was 7·5 and the effluent took up at least 1·9 parts of dissolved oxygen in 24 hours and failed to withstand incubation. At the time of drawing it had a strong sewage smell, but it must then have contained some nitrate, as this had changed to a doubtful earthy smell on the following morning. It was obvious, therefore, that for this strong sewage a contact of half an hour on the primary bed and of one and a half hours on the secondary bed was insufficient.

The following figures may also be found of interest.—

Parts per 100,000.	No. 3,387 (a good effluent) from a dilute sewage).	No. 3,526 (an indifferent effluent).		No. 3,527 (an effluent of fair quality).	
		Original.	Filtered through paper	Original.	Filtered through paper
"Oxygen absorbed" *at once*	0·26	0·92		0·41	
" " *in 4 hours*	1·00	2·78		1·57	
Incubator test (by smell)	Passed	Failed		Passed	
Solids in suspension	Trace	4·60		4·10	
Dissolved oxygen taken up *in 24 hours.*	24 Hrs. 0·04; 48 Hrs. 0·61; 72 Hrs. 0·85	0·67	0·13	24 Hrs. 0·33; 96 Hrs. 1·38	0·05

The effect of the suspended matter on the quantity of dissolved oxygen taken up in 24 hours is very marked in Nos. 3,526 and 3,527.

Bacteriological Notes.—Fourteen samples of secondary effluent were examined bacteriologically. The worst samples yielded positive results with the B. coli and presumptive tests for B. coli with 1/100,000 c.c. (100,000 per c.c.); the best samples positive results with 1/1,000 c.c. (1,000 per c.c.) Under more favourable conditions of working, it is probable that the secondary bed effluents would have usually yielded negative results with 1/10,000 c.c. (less than 10,000 per c.c.) As regards the B. enteritidis sporogenes test, the effluents usually contained from 10 to 100 spores of this anærobe per c.c.

Description of the Sample.	Number of B. Coli (or Gas-forming Coli-like Microbes).	B.S. = Bile Salt Glucose Peptone Test. N.R. = Neutral Red Broth Test. In. = Indol Test. L.P.M. = Lactose Peptone Milk Test.	B. Enteritidis Sporogenes Test.	Remarks.
3,097. Oswestry secondary bed effluent. 10/2/03.	—	100,000 N.R. 100,000 L.P.M.	1,000 not 10,000	
509. Oswestry secondary bed effluent. 30/3/03.	—	10,000 not 100,000 N.R.	100 not 1,000	
560. Oswestry secondary bed effluent. 18/6/03.	—	100,000 N.R.	100 not 1,000	
3,181. Oswestry secondary bed effluent. 6/7/03.	—	100,000 N.R.	At least 1,000	
3,246. Oswestry secondary bed effluent. 4/9/03.	—	10,000 not 100,000 N.R.	100 not 1,000	
3,247. Oswestry secondary bed effluent. 4/9/03.	—	10,000 not 100,000 N.R.	10 not 100	
3,264. Oswestry secondary bed effluent. 15/10/03.	10,000 not 100,000 (+ indol) (+ clot)	1,000 not 10,000 N.R.	1 not 10	
3,288. Oswestry secondary bed effluent. 4/11/03.	10,000 not 100,000 (− indol) (+ clot)	10,000 not 100,000 N.R.	100 not 1,000	
3,387. Oswestry secondary bed effluent. 16/2/04.	1,000 not 10,000 (+ indol) (+ clot)	1,000 not 10,000 N.R.	10 not 100	
3,388. Oswestry secondary bed effluent. 16/2/04.	1,000 not 10,000 (+ indol) (+ clot)	1,000 not 10,000 N.R.	10 not 100	
3,526. Oswestry secondary bed effluent. 27/7/04.	100,000 (− indol) (+ clot)	100,000 B.S. 100,000 N.R. 100,000 L.P.M.	10 not 100	
3,527.*Oswestry secondary bed effluent. 27/7/04.	100,000 (+ indol) (+ clot)	100,000 B.S. 100,000 N.R. 100,000 L.P.M.	100 not 1,000	
3,615. Oswestry secondary bed effluent. 30/1/05.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 B.S. 100,000 N.R.	100 not 1,000	
3,616. Oswestry secondary bed effluent. 30/1/05.	100,000 (+ indol) (− clot)	100,000 B.S. 10,000 not 100,000 N.R.	100 not 1,000	

Amount of Sewage treated.—A continuous daily record of the flow of settled sewage passing to the beds for treatment was kept by Mr. Lacey during the whole of our observations. From the yearly averages of these figures, we have estimated that the average daily flow treated by the double contact bed process during our observations has been approximately 436,000 gallons. On this basis, therefore, the quantities treated on the whole filtering area—primary and secondary beds together—were:—

Per square yard per 24 hours - - - - - 66 gallons.
Per cube yard per 24 hours - - - - - - 51·4 gallons.

On the basis of the dry weather flow of 350,000 gallons per day, the amounts treated would be:—

Per square yard per 24 hours - - - - - 53·3 gallons.
Per cube yard per 24 hours - - - - - - 41·2 gallons.

These figures are given for purposes of comparison.

* Single contact of crude sewage on secondary bed.

Effect of Temperature upon the working of the contact beds.—The general conclusion to be drawn from our temperature measurements at Oswestry is that the temperature of the effluents on both sets of beds follows that of the sewage, and is only slightly influenced by the temperature of the atmosphere. The observations included measurements made every few hours over a period of seven days, in May, **1902**, as well as others made on the occasion of each visit to the works.

SUMMARY.

The dry-weather sewage may be described as of about average strength. It is subject to large fluctuations of volume during rain. Considerable quantities of surface and subsoil water are known to enter the sewers, especially during the wet seasons of the year. On the Wednesday of each week the sewage receives the washings from a large cattle market and it contains, besides, some tannery and brewery refuse.

Only twice the dry-weather flow is ever treated at the works, any excess over this being run into a ditch which ultimately joins the river Morda, a tributary of the Severn.

The flow through the settling tanks is a rapid one, the sewage receiving only **4** hours continuous flow settlement in dry weather and much less in wet weather. The tanks, therefore, do not remove a great deal of the suspended solids of the sewage and are clearly too small for their purpose, especially as they are sludged only once in **6** weeks. In dry weather about **50** per cent. of the suspended matter of the crude sewage is deposited in these tanks, but in wet weather they probably serve only for grit settlement, and the issuing "settled" sewage may, in fact, contain more matter in suspension than the crude sewage.

The method by which the sewage sludge is disposed of at Oswestry has certain distinct advantages. By its admixture with the fine siftings of the cinder heap, the sludge dries much more quickly than if it were merely exposed in a lagoon, and it also appears in this condition to be more readily taken by farmers. The cinders, too, make it easier to manipulate, besides which they help to keep down nuisance from smell. There is never any serious accumulation of sludge on the works.

The construction of the primary beds is both simple and inexpensive and, although there has been occasional leakage from them, they may be taken generally as having answered their purpose. Leaks in beds constructed by simple excavation in this way are often difficult to locate, and this might constitute a serious defect in the case of a large installation; at Oswestry, however, there has been no serious difficulty on this account. There is a good deal to be said in favour of this inexpensive mode of construction for a small works in the country, which are built upon clay soil. At Oswestry the tops of the clay banks occasionally get rather sodden, and for this reason it is advisable to leave a fairly wide space between every two beds.

The house cinders with which the beds are filled were used for the sake of cheapness. They have several disadvantages, *e.g.*, they are light and therefore liable to displacement on the beds during the processes of filling and emptying, and they have also disintegrated considerably. For these reasons such cinders could not be recommended generally for large installations. On the other hand, though they are not by any means a perfect medium for contact beds, the economy in initial outlay effected by their use is a very material point for small country communities. When a primary bed has become clogged at Oswestry, it has been found cheaper to completely renew the material than to wash it.

Only a few samples of primary effluent were examined, most of them being dilute wet-weather samples. They showed a fair purification, although both the period of contact and the interval of rest were of necessity short, owing to the beds having lost so much in capacity. The primary effluents from strong dry-weather sewage would, of course, have contained more organic impurity.

Owing to the rapidity with which the primary beds had clogged, with **2** fillings per day of the poorly settled sewage, it was necessary to work them during our observations at a rate of **4** or **5** fillings per day, *i.e.* at such a rate as allowed them no chance of maintaining capacity. But, from the measurements made at the beginning of the observations, we formed the opinion that the beds required renewal at that time. Hence their economic "life," with **2** fillings per day of this badly settled sewage, was not more than **3** to **4** years.

The secondary beds are similar, as regards construction and material, to the primary beds, except that the cinders are rather smaller ($\frac{3}{8}$ to $1\frac{1}{4}$ in.). Although these beds have not clogged to anything like the same extent or at the same rate as the primary ones, treating as they did a liquor containing much less matter in suspension, the increase in the number of fillings per day *during* the observations left no doubt as to their having lost capacity considerably. Mr. Lacey estimates the "life" of those beds, as they have been worked, at about 7 to 8 years, and in this estimate we concur. No doubt some of the clogging might have been prevented by the use of smaller filtering material; but it must not be forgotten that this comparatively short "life" of the secondary beds has been due in part to the material of the primary beds not having been renewed at the proper time. The secondary beds have required less frequent forking than the primary, and they do not appear to have disintegrated to anything like the same extent.

The distribution on both primary and secondary beds is effected by means of wooden troughs laid on the surface of the material, the liquid rising in the trough and overflowing the sides. In this way it enters the bed gently, without disturbing the cinders (excepting in so far as the latter float). The troughs are altered in position from time to time, more particularly on the primary beds, the solid matter deposited in the immediate neighbourhood of the troughs being in this way distributed over the surface of the bed.

The total volume of sewage treated on the primary and secondary beds together, during the years 1903 to 1905, averaged 66 gallons per square yard, or 51·4 gallons per cube yard, per 24 hours, including the night sewage treated by single contact on the secondary beds alone.

The secondary effluents examined were not uniform as regards purification, no doubt because of the sewage being liable to somewhat unusual variations in strength and also because of the unequal periods of contact given on the primary beds; but the greater number of them were of fair quality. A little further purification would have made them quite satisfactory as final effluents, considered by themselves. In connection with this criticism it has to be borne in mind that these effluents were produced under unfavourable conditions, owing to the already clogged primary beds being kept at work, at our request, much longer than they would have been in the ordinary course. Had the material of the beds been renewed, so as to allow of their giving a contact of 2 hours (instead of $\frac{1}{2}$ to 1 hour, as was actually the case), we think that the final effluent would undoubtedly have been much more uniform as regards purification, and this even with the poor settlement given to the sewage in the settling tanks.

We are unable to express an opinion as to the general quality of the effluent obtained—without any preliminary tank settlement—by single contact of the night sewage on the secondary beds, having examined only one sample (this was of good quality, apart from the 4 parts of suspended solids which it contained). This method of treating the night sewage was adopted at Oswestry with the object of relieving the primary beds, but the procedure was attended with obvious disadvantages, and it has recently been discontinued. For example, unless a special settling tank be provided, it may at times involve the treatment of rather strong unsettled storm sewage, containing solid matter washed out of the sewers. If sufficient tank capacity is available for good settlement of the whole 24 hours' flow, the weaker night sewage serves to dilute the stronger day sewage, *i.e.* the liquid as a whole tends to become equalized as regards strength. It can then all be treated on a uniform plan, without throwing upon the workman in charge at night the responsibility of deciding what degree of treatment shall be given to a part of it.

Since a large portion of the storm sewage at Oswestry is diverted into the outflow ditch, no observations could be made as to the effect of the effluent upon the water in the ditch.

Some little smell arises during the sludging operations, but we have never observed any serious nuisance from smell on the works upon the occasions of our visits.

The working cost of treating the Oswestry sewage is low. As the initial cost of construction was also small, the whole process of sewage purification at Oswestry may be looked upon as an inexpensive one.

We are indebted to Mr. G. W. Lacey, Borough Surveyor of Oswestry, and also to Messrs Richard and David Jones, who have charge of the sewage works, for assistance in connection with our work at Oswestry.

PRESTOLEE SEWAGE WORKS.

(Bury Rural District Council.)

1. Situation of works - - - - -	About 300 yards from the centre of the population.
2. Method of treatment - - - - -	Closed septic tank, followed by intermittent filtration through percolating filters of fine material.
3. Population draining to works during observations	500 (estimated average).
4. Water supply in gallons per head and whence obtained - - - - - - -	17·7; Bolton Corporation. Water has an average hardness of about 3° per gallon.
5. Number of W.C.'s - - - - - -	2.
6. Sewerage system - - - - - -	Separate.
7. Average dry weather flow of sewage in gallons per 24 hours - - - - - -	18,000.
8. Gallons of sewage per head per day - -	36.
9. Character of the sewage - - - - -	Extremely weak and almost entirely a slop water sewage.
10. Period of observations - - - - -	November, 1902, to January, 1905
11. Age of filters - - - - - - -	From 1 to 3½ years.
12. Amount of storm water treated - - -	The whole of it which reaches the works (3 or 4 times the dry weather flow).
13. Capacity of tank in gallons - - - -	16,625.
14. Total area of filters in yards super. - - -	237·3.
15. Total content of filters in yards cube - -	395·5.
16. Nature of filtering material - - - -	Cinders and gravel.
17. Gallons of septic tank liquor treated per yard super. per 24 hours (all filters included) -	92·7.
18. Gallons of septic liquor treated per yard cube per 24 hours (all filters included) - -	55·6.
19. The final effluent is discharged into - - -	The river Irwell.

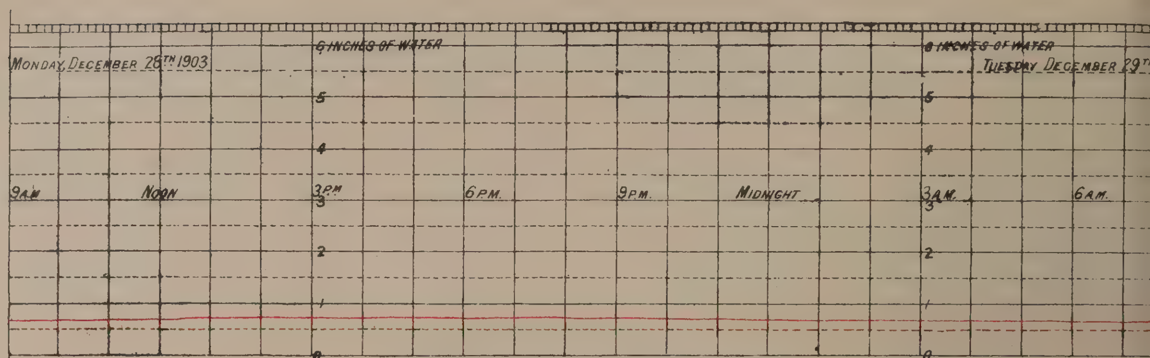
Diagram W.

Diagrams showing flow of Sewage at Prestolee.

as falling over a Weir 8" wide.

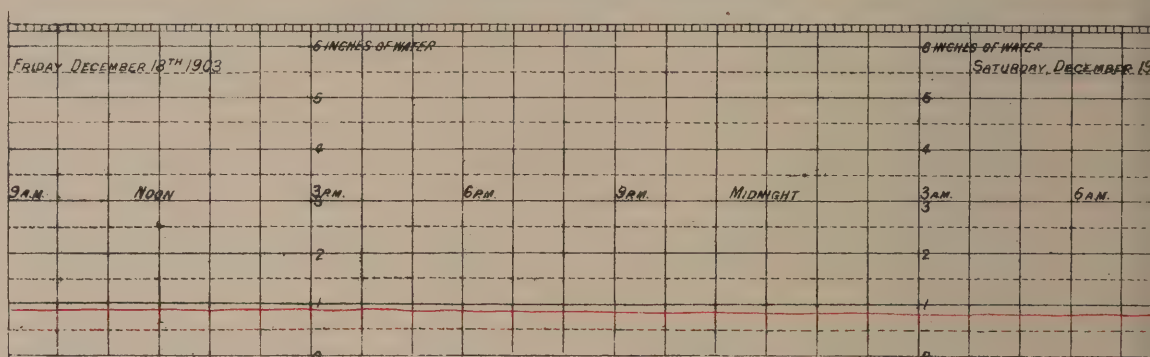
Note:- Over a Weir 8" wide ·75 of an inch = a rate of 18,144 gallons per 24 hours.
1·0 inch = " " " 27,864 " " " "
1·25 inches = " " " 38,880 " " " "
1·50 " = " " " 50,976 " " " "

Dry day.
Rainfall nil.



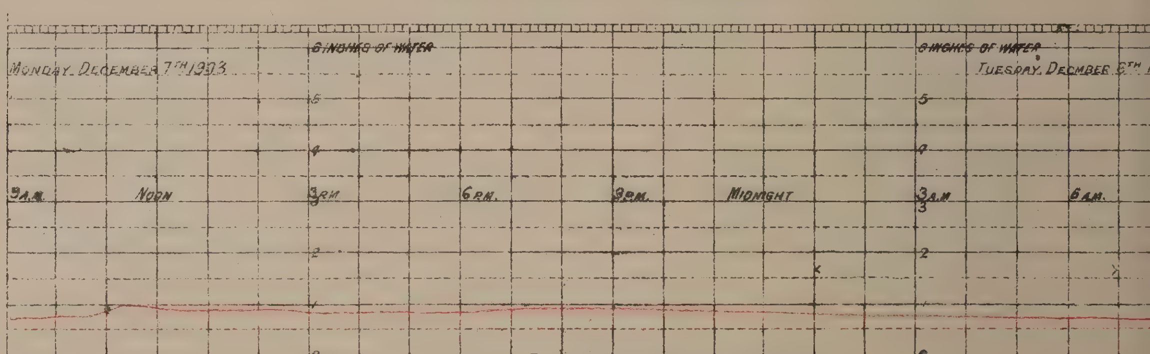
TOTAL FLOW FOR THE DAY = 18,000 GALLONS.

Rainfall
0·06 inch.



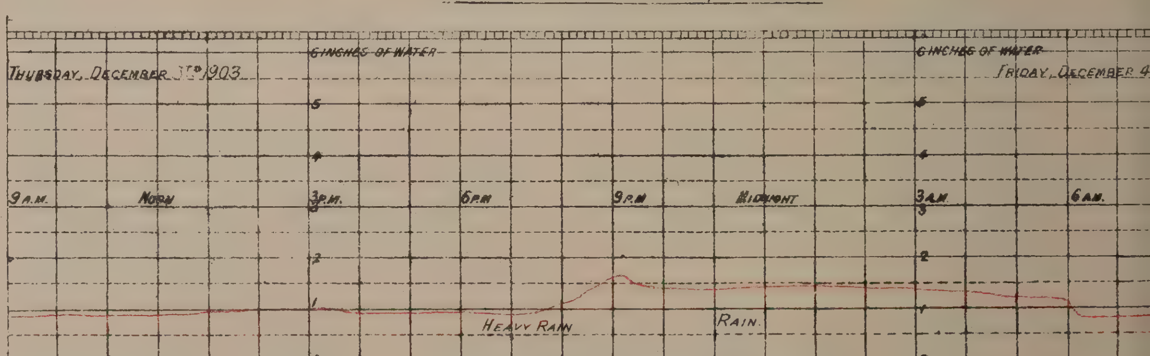
TOTAL FLOW FOR THE DAY = 22,000 GALLONS.

Wet day,
Rainfall
0·25 inch.



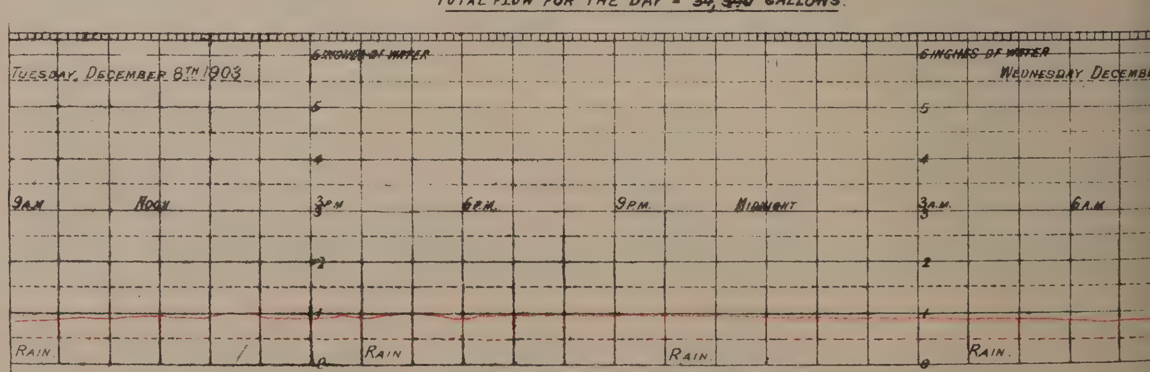
TOTAL FLOW FOR THE DAY = 20,660 GALLONS

Wet day,
Rainfall
0·49 inch
(Falling in 5 hours).



TOTAL FLOW FOR THE DAY = 34,340 GALLONS.

Wet Day,
Rainfall
0·43 inch
(Falling over whole day).



TOTAL FLOW FOR THE DAY = 23,840 GALLONS.

FLOW OF SEWAGE.

Notwithstanding the fact that the area is drained on the separate system, the flow of sewage is considerably affected by heavy rain and, as there are no storm overflows on the sewerage system, the whole of the storm water entering the sewers is brought to the works and treated. The actual increase in volume, however, is very small for ordinary light falls of rain, and is apparently not more than three or, at the most, four times the dry weather flow for heavy rainfalls of half-an-inch and upwards.

The maximum flow measured at Prestolee during the gauging operations, which lasted throughout the month of December, 1903, was at the rate of 58,500 gallons per 24 hours, or rather more than three times the dry weather flow, while the maximum 24 hours' flow, which occurred on the same day, was 34,350 gallons. Both of these maxima were the result of a rainfall of ·49 inch, falling upon fairly dry ground within a period of five hours. As a rainfall of this kind does not occur very frequently, it would therefore appear that a flow at the rate of more than three times the dry weather flow is seldom brought to the Prestolee works.

The flow of sewage at Prestolee was measured continuously throughout the month of December, 1903. Although a fair quantity of rain fell in the district during the first week of this period, the remainder of the time was exceptionally dry, only ·25 of an inch falling in 21 days. During the last week of the month, therefore, which was perfectly dry, good records of the dry weather flow were obtained. The average dry weather flow during this week was approximately 18,000 gallons per 24 hours, and this is therefore taken as the dry weather flow.

The highest day's flow of 20,000 gallons occurred on the Thursday and Friday of the week, and the lowest day's flow of 16,500 on the Saturday and Sunday.

Owing, no doubt, to the very large infiltration of subsoil water and the low gradient of the sewer, the dry weather flow is of an extraordinary even character, so even, in fact, that, with the exception of slight variations, which as a rule take place between midday and 10 p.m., it may be said to be an almost constant flow.

When heavy rain falls upon the area, considerable, but still more or less gradual, fluctuations occur. During the measurements the greatest increase of volume due to rain was in the proportion of three to one within two hours.

For the whole month of December, the average daily flow was approximately 22,000 gallons, or 22 per cent. above the dry weather flow. The rainfall during this period was about half the average rainfall for December (1·8 inches as against 3·67). Although, therefore, the daily flow is certainly low for December, we think it probable that the figure gives a fair idea of the average daily flow for the whole year.

Subsoil Water.—All the facts go to show that a preponderating quantity of subsoil or ground water enters the sewers The sewage flow is almost constant, the sewage is extremely weak in character, and the water supply accounts for less than half of the dry weather flow. The lowest night flow measured was at the rate of 14,000 gallons per 24 hours. If this is taken to be mostly subsoil water, it would seem that the proportion of sub-soil water to sewage is something like three volumes to one.

On Diagram W will be found some illustrations of the sewage flow at Prestolee.

Crude Sewage.—Three sets of hourly samples, Nos. 3,319, 3,323 and 3,327, one sample of weakest night sewage, No. 3,222, and one ordinary chance sample, No. 3,127, were examined chemically. The hourly samples were drawn over the usual three days at the beginning of December, 1903, in dry frosty weather following a wet week; the ground was frozen on the surface, but that would not prevent subsoil water finding its way into the sewers. The sample of weak night sewage was also drawn at this time. The remaining chance sample, No. 3,127, was taken on Wednesday, March 18th, 1903, at 8 a.m., after heavy rain during the night, which did not, however, appear to have much affected the flow.

The following figures were obtained :—

Parts per 100,000		Hourly Samples.		Chance Samples.	
		Average.	Number of Estimations.	Weak Night Sample No. 3,222.	No. 3,127.
Ammoniacal Nitrogen	(0·34 to 0·47)	0·42	(3)	0·19	
Albuminoid Nitrogen	(0·12 to 0·17)	0·15	(3)	0·07	
Total Organic Nitrogen	(0·27)		(1)		
Oxidized Nitrogen	(0·48 and 0·26)		(2)		0·0
Total Nitrogen	(0·98 to 1·11)	1·03	(3)		1·10
"Oxygen absorbed" *at once*, at 27° C.	(0·71 to 0·76)	0·73	(3)	0·34	0·65
" " *in 4 hours*	(3·06 to 4·14)	3·57	(3)	1·28	2·54
Chlorine	(2·74 to 2·90)	2·84	(3)	1·92	
Solids in Suspension	(3·36 to 7·20)	5·42	(3)	4·40	
Solids by Centrifuge (vols.)	(31·0 to 51·0)	43·0	(3)	61·0	52·0
Ratio of Solids in Suspension to Centrifuge Solids	1 : 7·1 to 1 : 9·2	1 : 8·1	(3)	1 : 13·9	

The above figures show the sewage at Prestolee to be abnormally weak in character. The hourly samples (which were very uniform in composition and had a soapy smell) contained only about one part of total nitrogen and gave a 4 hours' "oxygen absorbed" figure of 3·56, while all of them contained some nitrate, no doubt from the presence of subsoil water. The suspended solids, which were very flocculent, only averaged 5·4 parts. The chance sample, No. 3,127, had much the same composition as the hourly samples. The sample of weak night sewage, No. 3,222, was excessively dilute and also contained some nitrate. Thus, even if the foregoing samples are weaker than the true average over a dry year, there can be no question as to the very dilute character of the sewage which the tanks and filters have to treat.

Bacteriological Notes.—The sewage was very weak from the bacteriological point of view. Three out of the four samples yielded negative results with ·0001 c.c. (less than 10,000 per c.c.) with the B. coli and neutral red broth tests. Further, three out of four samples contained less than 10 spores of B. enteritidis sporogenes per c.c.

Description of the Sample.	Number of B. Coli (or gas-forming Coli-like microbes).	B.S. = Bile-salt glucose peptone test. N.R. = Neutral red broth test. In. = Indol test. L.P.M. = Lactose peptone milk test.	B. Enteritidis sporogenes test.	Remarks.
3319. Prestolee Crude Sewage, 1/12/03.	1,000 not 10,000 (+ indol) (+ clot)	1,000 not 10,000 N.R.	Less than 10	
3322. Prestolee Crude Sewage, 2/12/03.	1,000 not 10,000 (− indol) (− clot)	1,000 not 10,000 N.R.	Less than 10	
3323. Prestolee Crude Sewage, 2/12/03.	1,000 not 10,000 (+ indol) (+ clot)	1,000 not 10,000 N.R.	Less than 10	
3327. Prestolee Crude Sewage, 3/12/03.	100,000 (+ indol) (− clot)	100,000 N.R.	10 not 100	

DETRITUS TANK.

Number - - - - - - -	1.
Size - - - - - - - -	9 feet by 5 feet.
Depth of water - - - - -	3 feet 6 inches.
Capacity - - - - - - -	984 gallons.

Construction.—The detritus tank is a rectangular tank constructed of brick and cement, with a concrete bottom. It is fitted with a $\frac{3}{4}$ inch screen and a scum-board.

Working.—The tank receives the whole flow of sewage, night and day. It is cleaned out once a week by means of a scoop, the sludge being deposited in a small lagoon situated at the side of the tank. When the sludge is sufficiently dry, it is thrown up on to a heap and used as a top dressing for grass land, as occasion requires.

SEPTIC TANK.

Number - - - - - - -	1.
Size - - - - - - - -	38 feet by 10 feet.
Depth of water - - - -	7 feet.
Capacity - - - - - - -	16,625 gallons.

Construction.—The septic tank is a simple rectangular chamber constructed of brick and cement walls, with a concrete bottom, and covered with a brick arch over which a layer of soil is spread. The sewage enters the tank at the water level through a single inlet pipe, and issues (also at the water level) through a pipe placed at one of the extreme corners of the outlet end. The outlet is protected by a scum-board.

Flow through.—With a dry weather flow of 18,000 gallons per 24 hours, the flow through the tank would be once in 22 hours, at the rate of ·34 inch per minute.

Working.—The tank receives the whole flow of sewage, day and night. It was first brought into use in March, 1899, and has not yet been cleaned out (January, 1906). This lengthened period of use is probably to some extent due to the fact that the sewerage system is practically a separate one, and that therefore not much heavy mineral matter is brought to the works.

Septic Tank Liquor.—Three sets of hourly samples and eight chance (including five experimental) samples were examined chemically. The hourly sets, Nos. 3320, 3324 and 3329, were of course drawn at the same time and under the same conditions as the hourly sets of sewage. They gave the following figures:—

———	Parts per 100,000	Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - - - - - -	(0·49 to 0·53)	0·52	(3)
Albuminoid Nitrogen - - - - - - - - -	(0·16 to 0·17)	0·17	(3)
Total Organic Nitrogen - - - - - - - -	(0·36 to 0·44)	0·40	(3)
Total Nitrogen - - - - - - - - -	(0·85 to 0·97)	0·91	(3)
"Oxygen absorbed" *at once*, at 27° C. or 80° F. - - -	(0·44 to 0·70)	0·59	(3)
" " *in* 4 *hours* - - - - - - -	(2·41 to 3·09)	2·84	(3)
Chlorine - - - - - - - - - - - -	(2·82 to 2·90)	2·85	(3)
Solids in Suspension - - - - - - - - -	(2·52 to 3·80)	3·17	(3)
Solids by Centrifuge (vols.) - - - - - - -	(22·0 to 26·0)	25·0	(3)
Ratio of Solids in Suspension to Centrifuge Solids - -	(1 : 6·8 to 1 : 8·7)	1 : 7·9	(3)

These three hourly sets of septic tank liquor were to all intents and purposes identical in composition. They were all opalescent and turbid, with small quantities of blackish deposit and a somewhat sour septic tank smell. It will be observed that the chemical figures of analysis are almost the same as those given by the hourly samples of sewage, the percentage reduction on the latter being very small, thus :—

Calculated on.	Reduction.
Total Nitrogen	12 per cent.
Albuminoid Nitrogen	No reduction.
"Oxygen absorbed" *in* 4 *hours*	20 per cent.
Suspended solids	42 per cent.

The septic tank liquor is thus remarkably dilute.

The eight chance samples of septic tank liquor examined were Nos. 3,043, 3,076, 3,164, 3,206A, 3,587, 3,590, 3,593 and 3,595. The first two of these were drawn in the months of November and December, 1902, the next two in June and August, 1903, and the last four in January, 1905, these four being samples taken at the same time as the experimental samples of effluent referred to later in this Report; they were similar in composition to the first four, so are included here. Six out of the eight were drawn in the cold months of the year. The weather at the times when the samples were taken was mostly dry, or dry after wet.

The following results were obtained :—

——	Parts per 100,000	Average.	Number of Estimations.
Ammoniacal Nitrogen	0·50 to 0·76)	0·70	(5)
Albuminoid Nitrogen	(0·17 to 0·27)	0·21	(5)
Total Nitrogen	0·86 and 1·46)		(2)
"Oxygen absorbed" *at once*, at 27° C.	0·55 to 0·95)	0·72	(7)
,, ,, *in* 4 *hours*	(2·49 to 3·64)	3·17	(8)
Chlorine	(2·20 to *8·34)	3·87	(6)
Solids in suspension	(2·80 to 7·50)	5·04	(4)
Solids by centrifuge (vols)	(15·0 to 29·0)	23·0	(7)
Ratio of solids in suspension to centrifuge solids	(1 : 3·8 to 1 : 10·4)	1 : 6·6	(3)

* No. 3043 gave this (relatively) high figure for chlorine; the chlorine, in the other five samples in which it was determined, varied between 2·20 and 3·36, *i.e.*, it was the same as in the hourly samples.

Like the hourly samples, these chance samples of septic tank liquor were of very even composition throughout, and they were uniformly very dilute, though on the whole slightly stronger than the hourly samples. The average centrifuge figure for solids was almost the same in both, but the chance samples as a whole probably contained rather more suspended solids than the hourly samples. The dilute character of this liquor was well exemplified by No. 3,595, which was of nearly the average strength, but only took up 1·2 parts of oxygen from water in 24 hours, when diluted with 3 volumes of tap water.

Compared with the hourly samples of sewage, the chance samples of septic tank liquor show the following differences in figures:—

Calculated on :—	——	Number of Estimations.
Ammoniacal Nitrogen	67 per cent. increase	(5)
Albuminoid Nitrogen	40 " "	(5)
"Oxygen absorbed" *at once*	0 " "	(7)
Oxygen absorbed *in 4 hours*	11 " reduction	(8)
Solids in suspension	7 " "	(4)

It would seem, therefore, that a considerable digestion of solid matter was going on in the tank, or that the hourly samples of sewage were drawn at a time when the sewage was rather more dilute than the average. Probably both of these suggested explanations are correct.

Bacteriological Notes.—The samples of septic tank liquor usually gave positive results with the B. coli and presumptive tests for B. coli with ·0001 c.c. (10,000 per c.c.). As regards the B. enteritidis sporogenes test, the results varied from 10 per c.c. to less than 10 per c.c. Although the Septic tank liquor was weak bacteriologically, it cannot be said that the samples of tank liquor were purer (bacteriologically) than the exceptionally weak crude sewage. Indeed, if anything, the crude sewage yielded better results. This is in agreement with the chemical figures.

As regards the samples of Septic tank liquor which were drawn at the same time as the samples of experimental effluent, the bacteriological results were very similar to those already described.

Description of the Sample.	Number of B coli (or gas-forming coli-like microbes).	B.S.=Bile-salt glucose peptone test. N.R.=Neutral red broth test. In.=Indol test. L.P.M.=Lactose peptone milk test.	B. enteritidis sporogenes test.	Remarks.
3044. Prestolee septic Tank liquor, 4/11/02.	100,000 (– indol) (– clot)	100,000 In. 100,000 L.P.M.	10 not 100	
3076. Prestolee septic tank liquor, 17/12/02.	—	10,000 not 100,000 B.S. 10,000 not 100,000 N.R.	10 not 100	"Gas" test + ·1 c.c. (24 hours at 20°C.) Number of bacteria (agar at 37°C) 120,000 per c.c.
3164. Prestolee septic tank liquor, 10/6/03.	—	100,000 N.R.	10 not 100	
3320. Prestolee septic tank liquor, 1/12/03.	1,000 not 10,000 (+indol) (+clot)	1,000 not 10,000 N.R.	10 not 100	
3324. Prestolee septic tank liquor, 2/12/03.	10,000 not 100,000 (+indol) (– clot)	10,000 not 100,000	Less than 10	
3329. Prestolee septic tank liquor, 3/12/03.	10,000 not 100,000 (+indol) (– clot)	10,000 not 100,000	Less than 10	
3587. Prestolee septic tank liquor, experimental, 4/1/05.	10,000 not 100,000 (+indol) (+clot)	10,000 not 100,000 B.S. 10,000 not 100,000 N.R.	Less than 10	
3590. Prestolee septic tank liquor, experimental, 5/1/05.	10,000 not 100,000 (– indol) (– clot)	10,000 not 100,000 B.S. 100,000 N.R.	10 not 100	
3593. Prestolee septic tank liquor, experimental, 6/1/05.	1,000 not 10,000 (+indol) (+clot)	1,000 not 10,000 B.S. 1,000 not 10,000 N.R.	10 not 100	
3595. Prestolee septic tank liquor, experimental, 9/1/05.	10,000 not 100,000 (+indol) (+clot)	10,000 not 100,000 B.S. 10,000 not 100,000 N.R.	1 not 10	

FILTERS.

Number - - - - - -	3.
Size of each - - - - -	27 feet 9 inches by 25 feet 8 inches.
Area of each - - - -	79·11 square yards.
Total area - - - - -	237·33 square yards.
Depth of material - - - -	5 feet.
Cubic content of each - - -	131·85 cube yards.
Total cubic content - - -	395·5 cube yards.
Material - - - - (Top)	1 foot fine cinders, $\frac{1}{4}$ to $\frac{1}{8}$ inch diameter ;
(Middle)	3 feet mixed cinders ;
(Bottom)	1 foot rough cinders.

Construction.—The filters are constructed below the level of the ground. They are completely enclosed on the four sides by brick and cement walls, and they rest on a concrete bottom. Air can only gain access to the interior of the filter either from the surface downwards, or upwards through the one outlet valve at the bottom, which is always kept open.

Distribution.—The distribution over the surface of each filter is effected by one main distributor, consisting of a six-inch half pipe laid diagonally across the surface of the bed. This feeds three branch-distributing channels, also constructed of half pipes. The channels are swept out every day after a bed has been used.

Underdraining.—The effluent is collected at the bottom of the filters by one main drain, which is carried diagonally across the concrete floor and fed from two branch collectors on either side.

Working.—Each filter receives the whole flow of septic tank liquor for a period of 24 hours, in turn. The general state of the installation, therefore, is—one filter working and two resting, so that a filter receives septic tank liquor for one day and rests for two days.

Except when it is necessary to remove the sludge which has accumulated on the top of the material, the filters require attention only once a day, and this only for a few minutes, in order to sweep the channels and alter the flow.

From the time when a filter is brought into use after being cleaned, the septic tank liquor delivered from the distributing channels gradually spreads outwards over the surface of the material, until, at the end of about a month, if the weather is dry, the whole surface becomes clogged; during wet weather this clogging may take place in half the time. When clogging occurs, the thin coating of sludge is removed, together with the cinders which adhere to it, by means of a shovel. A thin layer of fresh cinders is then spread over the filter, and after this has been patted down, the filter is again ready for use. The clogged cinders are spread out to dry at the side of the filter. After lying exposed to the air for some time, they can be riddled and used again.

Age of filters.—Beds Nos. 1 and 2 were first brought into use in March, 1899. No. 3 was not started till August, 1901.

Amount of Septic Tank Liquor treated upon the filters.—On the basis of an average daily flow of 22,000 gallons, the quantities of septic tank liquor treated over the whole filtering area are :—

Per square yard per 24 hours, 92·7 gallons.
Per cube yard per 24 hours, 55·6 gallons.

It has to be remembered, however, in reading these figures, that they are obtained by dividing the total area and total cubic content of all the filters into the daily flow. As only one filter is in use at a time, the actual rate at which the septic liquor passes on to any one filter is three times as much as this, *i.e.* :—

Per square yard per 24 hours, 278 gallons.
Per cube yard per 24 hours, 166·8 gallons.

On the basis of the dry-weather flow of 18,000 gallons per 24 hours, the quantities treated are :—

Per square yard per 24 hours, 75·8 gallons.
Per cube yard per 24 hours, 45·5 gallons.

Effluents.—Three sets of hourly samples, six ordinary chance samples, and six experimental samples were examined chemically. The hourly sets, Nos. 3,321, 3,325, and 3,330 were drawn at the same time and under the same conditions as the hourly samples of sewage and of tank liquor; hourly fractions were taken according to the rate of flow of the sewage. It was noted with regard to the first set, No. 3,321, that frost broke the surface of the bed to some extent, and let the liquid through without much ponding. No difference was, however, perceptible between the chemical purification here and that of the other two sets.

The following figures were obtained :—

——	Parts per 100,000	Average.	Number of Estimations.
Ammoniacal Nitrogen	(0·12 to 0·14)	0·13	(3)
Albuminoid Nitrogen	(0·03 to 0·04)	0·03	(3)
* Total Organic Nitrogen	(0·04 to 0·16)	0·10 approx.	(3)
Oxidized Nitrogen	(0·30 to 0·40)	0·33	(3)
Total Nitrogen	(0·46 to 0·69)	0·56	(3)
"Oxygen absorbed" *at once*, at 27° C.	(0·06 to 0·15)	0·10	(3)
,, ,, in 4 *hours*	(0·28 to 0·33)	0·31	(3)
Incubator test (Scudder)		3 passed	(3)
Incubator test (by smell)		3 passed	(3)
Smell when drawn		{ 2 good 1 slight sewage smell }	(3)
Smell when analysed		3 good	(3)
Chlorine	(2·70 to 2·88)	2·78	(3)
Solids by centrifuge (vols.)		Trace only	(3)

These three hourly sets of effluent were—practically speaking—identical from a chemical point of view. They were almost clear and colourless, with but a trace of suspended matter—in fact, they looked almost like water. The total nitrogen averaged only 0·56 part per 100,000, of which 0·33 part was nitric nitrogen; nitrous nitrogen was in every case absent on the day of analysis and practically none was found after incubation. The 4 *hours* "oxygen absorbed" figure was only 0·31. The last of the three sets was noted as having a faint but distinct odour of sewage when drawn, but none of the samples had any smell when analysed, and they all withstood the incubator test.

Compared with the hourly samples of septic tank liquor, we have the following reduction in figures :—

Calculated on :—	Reduction.
Total Nitrogen	38 per cent.
Ammoniacal Nitrogen	75 ,,
Albuminoid Nitrogen	82 ,,
Total Organic Nitrogen	75 ,,
"Oxygen absorbed" *at once*	83 ,,
,, ,, *in* 4 *hours*	89 ,,
Solids in suspension	100 ,,

* The quantity here was too small for accurate determination by an indirect method.

As judged by the hourly samples of effluent, therefore, the purification effected by the Prestolee filters on the dilute tank liquor is good, and a high-class effluent is produced.

Of the six ordinary chance samples of effluent examined—Nos. 3044, 3077, 3164A, 3207B, 3208 and 709—four were drawn in the summer and two in the winter months, partly in dry weather, and partly in dry weather shortly after wet. No. 3208 was a sample of drainings, taken $6\frac{1}{2}$ hours after septic tank liquor had ceased to be run on to the bed in use at the time; its figures of analysis, however, are practically the same as those given by the other samples, and so it is included here. The other five samples were drawn from beds which at the time had been receiving tank liquor for 11, $2\frac{1}{2}$, 9, $6\frac{1}{2}$ and $3\frac{1}{2}$ hours respectively. They may thus be taken as representing fairly enough the average working of the beds.

The following figures were obtained on analysis :—

	Parts per 100,000	Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - - -	(0·02 approx. to 0·06)	0·05	(4)
Albuminoid Nitrogen - - - - - - -	(0·01 to 0·02)	0·02	(3)
Oxidized Nitrogen - - - - -	(0·35 to 1·50 approx.)	0·90 ap.	(6)
"Oxygen absorbed" *at once*, at 27° C. - - - -	(0·03 to 0·28)	0·14	(6)
,, ,, *in 4 hours* - - - - -	(0·21 to 0·71)	0·41	(6)
Dissolved Oxygen taken up in 24 hours at about 18°C.	(0·02 to 0·10)	0·04 ap.	(6)
Incubator Test (Scudder) - - - - - -	* {5 passed {1 practically passed		(6)
,, ,, (by smell) - - - -	6 passed		(6)
Smell when drawn - - - - - - -	{5 good {1 faint sulphide smell		(6)
Solids by Centrifuge (Vols.) - - - - - -	(0·0 to 2·5)	Practically 0·0	(6)
Oxygen in solution when analysed - - - -	*c.c. per litre.* (1·9 approx. to 5·8)	4·4 c.c. ap.	(5)

Like the hourly samples of effluent, these chance samples were all clear and bright with practically no suspended matter, and with either no smell at all or only a faint earthy one on the day of analysis. With regard to their smell when drawn, No. 3,077 was noted as having a slight odour of sulphuretted hydrogen. This faint odour has been noticed on several occasions, but as a general rule the Prestolee effluents have a perfectly clean smell when drawn.

It may be said that almost the whole of the nitrogen they contained was in the oxidized state, and they not merely withstood incubation readily, but took up practically no dissolved oxygen in the process. They were thus effluents of very high class.

Compared with (*a*) the hourly and (*b*) the chance samples of septic tank liquor (taking the *whole* eight samples of the latter examined), these effluents show the following reduction in figures :—

Calculated on :—	Hourly.	Chance.
Ammoniacal Nitrogen - - - - - -	90 per cent.	93 per cent. reduction.
Albuminoid Nitrogen - - - - - - -	88 ,,	90 ,, ,,
"Oxygen absorbed" *at once* - - - - - -	76 ,,	81 ,, ,,
,, ,, *in 4 hours* - - - - -	79 ,,	87 ,, ,,
Solids in Suspension - - - - (Practically)	100 ,,	100 ,, ,,

* One of these is taken for granted.

Bacteriological Notes.—Generally speaking, the B. coli test and presumptive tests for B. coli yielded positive results with from ·01 to ·001 c.c. (100 to 1,000 per c.c.). Nearly all the samples yielded negative results with 1 c.c. with the B. enteritidis sporogenes test. Sample 3,077 contained only 2,600 microbes per c.c. (agar at 37° C.). Apart from the question of the weak nature of the sewage being treated, the effluents were very good bacteriologically.

As regards the experimental samples, the results remained good even under the conditions of experiment.

Description of the Sample.	Number of B coli (or gas-forming coli-like microbes).	B.S. = Bile-salt glucose peptone test. N.R. = Neutral red broth test. In = Indol test. L.P.M. = Lactose peptone milk test.	B Enteritidis sporogenes test.	Remarks.
3045 Prestolee effluent, 4/11/02	10,000 not 100,000 (+indol) (+clot)	100,000 L.P.M. 10,000 not 100,000 In.	1 not 10	
3077 Prestolee effluent, 17/12/02	—	100 not 1,000 B.S. 100 not 1,000 N.R.	Less than 1	"Gas" test, negative 1 c.c. 24 hrs. at 20° C. Number of bacteria, 2,600 per c.c. (agar at 37° C.).
3164B Prestolee effluent, 10/6/03	—	100 not 1,000 N.R.	Less than 1	
3207B Prestolee effluent, 4/8/03	—	Less than 100 N.R.	Less than 1	
3207 Prestolee effluent drainings, 4/8/03	—	Less than 100 N.R.	Less than 1	
3321 Prestolee effluent, 1/12/13	100 not 1,000 (+indol) (+clot)	100 not 1000 N.R.	10 not 100	
3325 Prestolee effluent, 2/12/03	1,000 not 10,000 (+indol) (+clot)	1,000 not 10,000 N.R.	Less than 1	
3330 Prestolee effluent, 3/12/03	1,000 not 10,000 (+indol) (+clot)	1.000 not 10,000 N.R.	Less than 1	
709 Prestolee effluent, 15/6/04	1,000 not 10,000 (+indol) (+clot)	1,000 not 10,000 B.S. 100 not 1,000 N.R.	Less than 1	
3588 Prestolee effluent, experimental, 4/1/05	100 not 1,000 (+indol) (—clot)	100 not 1,000 B.S. 1,000 not 10,000 N.R.	Less than 10	
3589 Prestolee effluent, experimental, 4/1/05	1,000 not 10,000 (—indol) (—clot)	1,000 not 10,000 B.S. 1,000 not 10,000 N.R.	Less than 1	
3591 Prestolee effluent, experimental, 5/1/05	1,000 not 10,000 (—indol) (—clot)	1,000 not 10,000 B.S. 1000 not 10,000 N.R.	1 not 10	
3592 Prestolee effluent, experimental, 5/1/05	1,000 not 10,000 (+indol) (+clot)	1,000 not 10,000 B.S. 1,000 not 10,000 N.R.	1 not 10	
3594 Prestolee effluent, experimental, 6/1/05	1,000 not 10,000 (—indol) (+clot)	1,000 not 10,000 B.S. 1,000 not 10,000 N.R.	Less than 1	
3596 Prestolee effluent, experimental, 9/1/05	10,000 (+indol) (+clot)	10,000 B.S. 10,000 N.R.	Less than 1	

Effect of Temperature upon the Working of the Filters.—The temperature observations at Prestolee have included a set of temperature measurements, made every few hours over a period of three days in cold, frosty weather, and also isolated measurements made on the occasion of each visit to the works. Notwithstanding the frost which prevailed during the greater part of the time when the former measurements were being made, the temperature of the effluent never fell below 7°C. (44·6°F.), even although at the time the temperature of the atmosphere was −3·2°C. (26·2°F.)

It is interesting to observe also, that the temperature of the tank liquor was, as a rule, slightly higher than that of the sewage. The lowest effluent temperature measured during any visit to the works was 6·0°C. (42·8°F.); this was in January, 1905, when the temperature of the atmosphere was 5°C. (41°F.) and a strong east wind prevailed.

Speaking in regard to ordinary frost (for we have had no experience of very severe weather at Prestolee), we have concluded from these observations that the temperature of the sewage and effluent is only slightly affected during cold weather, and that it is more affected by a cold wind than by frost.

Experiment to ascertain the Effect of keeping one of the Filters ponded for a lengthened Period.

In order to gain some idea of how long it would be possible to work one of the fine Prestolee filters, treating the dilute tank liquor there, the following experiment was made :—

On Wednesday, January 4th, 1905, at 2.30 p.m., Septic tank liquor was turned on to Bed No. 1, which had previously been rested for 29½ hours, *i.e.*, a shorter period of rest than the usual two days. At this time the weather was fairly dry, but the ground was wet. The first sample of effluent from the bed was drawn 30 minutes after the start, at which time the effluent had begun to flow out at a fair rate, and others were taken from time to time, as detailed below. The experiment lasted until January 9th, at 4.20 p.m., *i.e.*, for fully five days, the weather for the greater part of this time being showery, but the flow of sewage never much above the normal.

During the course of the experiment four samples of septic tank liquor were drawn viz. :—

No. 3587 on January 4th at 2.30 p.m.

No. 3590 on January 5th at 10.45 a.m.

No. 3593 on January 6th at 9.45 a m.

No. 3595 on January 9th at 4.0 p.m.

As already stated, these samples were very much alike in composition, and their figures of analysis are therefore averaged here and placed in one column, beside the figures for each of the experimental effluents, which are given separately. Those effluents were :—

No. 3588	Drawn	Jan. 4th,	30 minutes	after	starting bed;	
„ 3589	„	„ 4th,	6½ hours	„	„	; bed three quarters ponded.
„ 3591	„	„ 5th,	20¾ „	„	„	; bed four-fifths ponded.
„ 3592	„	„ 5th,	27½ „	„	„	; bed ponded nearly all over.
„ 3594	„	„ 6th,	43¾ „	„	„	; bed nine-tenths ponded.
„ 3596	„	„ 9th,	121½ „	„	„	; bed completely ponded.

The analyses are as follows:—

—	Average of Four Septic Tank Liquors.	Effluents. Nos. 3588	3589	3591	3592	3594	3596
Drawn - - - - -		Jan. 4th.	Jan. 4th.	Jan. 5th.	Jan. 5th.	Jan. 6th.	Jan. 9th.
Analysed - - - -		,, 5th.	,, 6th.	,, 6th.	,, 9th.	,, 9th.	,, 10th.
Parts per 100,000							
Ammoniacal Nitrogen - - -	0·75(4)*	0·04	0·19	0·28	0·26	0·32	0·60
Albuminoid Nitrogen - - -	0·22 (4)	0·07	0·06	0·05	0·07	0·07	0·07
Oxidized Nitrogen - - -		0·90	0·44	0·40	0·32	0·27	0·00
"Oxygen absorbed" *at once*, at 27° C. - - - - - -	0·76 (4)	0·14	0·23	0·17	0·29	0·35	0·31
,, ,, *in* 4 *hours* -	3·21 (4)	0·56	0·91	0·47	0·77	0·81	0·65
Dissolved Oxygen taken up in 24 hours at 18°C. - - - -	1·20 (1)	0·48	0·62	0·85	0·56	0·66	0·55
Incubator Test (Scudder) - -		Passed	Passed	Passed	Passed	Passed	Failed
Incubator Test (by smell) - -		Passed	Passed	Passed	Passed	Passed	Failed
Smell when drawn - - -		Faint soapy	Good	Good	Good	Good	Strong sewage
Smell when analysed - - -		Slight soapy and earthy	Slight soapy	Good	Slight soapy and earthy	Good	Slightly unpleasant
Chlorine - - - - - -	2·93 (4)						
Solids in suspension - - -	6·40 (2)						
Solids by centrifuge (vols.) - -	17·4 (3)	0·0	0·0	0·0	0·0	0·0	0·0
c.c. per litre.†							
Oxygen in Solution (when analysed) - - - - -		5·6	4·2	5·1	0·0	1·0	0·7

On examining the results of the foregoing experiment it is seen that, at 6½ hours after the start, the bed had become ponded over three-fourths of its surface and that the ponding gradually increased, but with fluctuations, until the bed was completely under water.

The septic tank liquor, during the whole of the experiment, was of about the same strength as all the other samples—both hourly and chance—examined from Prestolee, though with rather more suspended solids.

The experimental effluents, while of fair quality for the first two days (and indeed, one might infer, for the greater part of the five days over which the experiment lasted), did not even at the beginning approach the standard of the ordinary chance samples or of the hourly samples, previously examined. The first experimental sample had a slight

* The figures in brackets indicate the number of estimations in each case.

† In comparing the figures for dissolved oxygen found on the day of analysis, it is important to note that these estimations were made on the day after the samples were drawn, in the case of Nos. 3588, 3591 and 3596; two days after, in sample No. 3589; three days after, in No. 3594; and four days after, in No. 3592. The samples which could not be examined at once were kept in ice, but No. 3592 was at atmospheric temperature for two days after being drawn; this no doubt accounts for its oxygen being exhausted.

soapy smell when drawn and analysed, the next four an earthy smell, and the last sample a strong sewage smell when drawn and a slightly unpleasant one when analysed.

The figures for ammoniacal nitrogen and for nitric nitrogen (no nitrite being present in any sample on the day of analysis) show that there was a gradually decreasing oxidation as the experiment proceeded. The figures both for "oxygen absorbed" from permanganate and for dissolved oxygen absorption are less regular, but this is no doubt partly due to the fact that all the effluents could not be examined at equal intervals of time after they were drawn. Since all of them were free, or practically free, from suspended matter, they would no doubt exhaust any oxygen present in solution before trenching upon nitrate. In the case of No. **3,592**, for instance, no dissolved oxygen was found on the day of analysis, but nearly four days had elapsed since the effluent was drawn, and during nearly two of these it had stood at atmospheric temperature. Although, therefore, it contained no oxygen when analysed, it took up only a moderate quantity of oxygen from water during the next **24** hours.

In only one instance—the last sample—did the effluent fail to withstand incubation. The figures of this last analysis are particularly interesting, as exemplifying the case of a partially purified effluent from a weak sewage—an effluent which gives low figures for albuminoid nitrogen, for "oxygen absorbed" from permanganate, and for dissolved oxygen taken up from water, and which yet fails to withstand incubation, from lack of any nitrate to fall back upon. The case is of course an exceptional one, but it is none the less instructive.

We think that the general inferences to be drawn from this experiment, as regards the practical working of the beds at Prestolee, are:—

1. That beds used on this system can only be worked for a certain limited time without being rested; this has, of course, long been well known;

2. That the beds at Prestolee are worked well within their limits, that is to say, they are not called upon to receive liquid for such a length of time as to put a strain upon their aeration.

SUMMARY.

The sewage is, practically speaking, a slop-water sewage, and it is exceptionally weak in character because of the great infiltration of sub-soil water into the sewers.

The grit chamber is rather large—as grit chambers go—both in relation to the flow of sewage and to the size of the septic tank. It is cleaned out once a week, when a considerable quantity of grit sludge is removed from it; it thus aids materially in prolonging the period during which the septic tank can be run without sludging.

Like the sewage, the septic tank liquor is of course unusually dilute and, because of the separate sewerage system, it remains very uniform in composition. The suspended solids in the hourly samples averaged only **3·2** parts per **100,000** (as against **5·4** in the sewage), after the tank had been in use for four years; in four of the chance samples of septic tank liquor examined, these solids averaged **5** parts. It should be borne in mind here that the volume of liquid flowing through the tank does not vary within very wide limits—a circumstance which tends to uniformity in the quantity of suspended matter in the issuing liquid. Although, therefore, the percentage reduction by the septic tank of the suspended solids of the sewage is not very great, the filters have not much suspended matter to deal with.

Though we have made no accurate measurements of the quantity of sludge in the tank, we have satisfied ourselves that the tank was at least half full of sludge at the end of the observations, in January, **1905**, *i.e.*, after six years' working; and this receives corroboration from the fact that the surface layer of a filter now requires renewal about once in three weeks, whereas, at the beginning, once in three months sufficed. At the same time this difference is not entirely due to the increase in suspended solids in the tank liquor, but also to the circumstance that the flow of sewage at Prestolee is gradually getting larger. The tank has not yet been sludged, but its emptying will

probably present some difficulty, and a considerable quantity of sludge will have to be dealt with. Considering, however, the comparatively small size of the installation and the length of time that the tank has run, this cannot be considered a serious disadvantage to the process.

The filters are simply and cheaply constructed—as in fact, are the whole of the works. The grading of the filters appears to us to have been done with much judgment and without unnecessary refinement. The bottom layers are of comparatively coarse material, while the surface layer—made up of particles $\frac{1}{4}$ inch to $\frac{1}{8}$ inch in diameter and periodically renewed—is sufficiently fine to prevent the entrance of suspended matter into the body of the filter; at the same time the use of such fine material renders periodical renewal of the surface necessary, if clogging is to be avoided. In the case of Prestolee the use of cinders for filtering material has been quite successful, although at some other places they have been found to disintegrate badly.

One point which may seem open to criticism is that the filtering material rests directly upon a concrete floor, the only opening in the base being at the outlet valve. It would, no doubt, have given a greater "reserve of æration"—if the term may be allowed—had the material rested on a false bottom, and had one side, at any rate, of the containing walls been pigeon-holed along the base; still, four of the five ordinary chance samples of effluent, which were tested for dissolved oxygen, were found to be well ærated.

Both the hourly and chance samples of effluent examined were of high class, chemically; the chance ones of very high class. This was, of course, mainly due to the fact that, on the average, only **93** gallons per square yard, or **56** gallons per cube yard, of a *very dilute* tank liquor were being treated; but still, the satisfactory result of the filtration remains. Bacteriologically, the *actual* results were very good, but it must also be borne in mind here that the tank liquor itself was exceptionally weak in bacteria.

The experiment upon the ponding of a bed at Prestolee for a lengthened period again showed that beds of this nature can only purify tank liquor for a limited period of time, after which they require to be rested, and—at a longer interval—to have their surfaces scraped and renewed. The degree of purification effected by such filters, therefore, depends upon the length of time that they are fed with tank liquor, and upon the condition of their surface material; the latter must be clean and at the same time well consolidated. In other words, good management tells very largely upon this class of installation. The design of the whole works at Prestolee is eminently suited to the proper treatment of the class of sewage.

Apart from the local smell which arises when the grit chamber is being cleaned out weekly, we have never noticed any nuisance on our visits to the Prestolee works.

The results show that a sewage installation for a small community—where the sewage is dilute—can be constructed on inexpensive lines and worked economically, and yet be efficient

The volume and condition of the river Irwell at Prestolee are such as to render impracticable any observations as to the effect of the effluent upon the river water There have, however, been no signs of particular growths in the effluent outfall pipe or in the water close to it.

We should like, in conclusion, to take this opportunity of acknowledging the assistance given to us during our observations at Prestolee by Mr. C. C. Hooley, who designed the works, and by Mr. James Haydock, who has charge of the installation.

ROCHDALE SEWAGE WORKS (ROCH VALLEY OUTFALL).

Corporation of Rochdale.

1. Situation of works - - - -	Roch Mills.
2. Method of treatment - - - -	(1) *General Process.*—1,450,000 gallons per 24 hours, made up of (1) the Roch Valley sewage, 1,150,000 gallons per 24 hours; and (2) the Sudden Valley sewage, 300,000 gallons per 24 hours. Chemical precipitation and continuous-flow settlement, followed by treatment either upon land or upon double-contact beds. (2) *Experimental Process.*—About 160,000 gallons per 24 hours (constant quantity). Open septic tank treatment and percolating filtration through Whittaker & Bryant filters, followed by partial settlement in a continuous flow effluent tank.
3. Population draining to Roch Valley outfall during observations.	About 52,000.
4. Water supply in gallons per head and whence obtained.	18 gallons per head. Corporation water works —a fairly soft water.
5. Number of W.C.'s - - - -	900 water closets, 540 waste-water closets.
6. Sewerage system - - - -	Combined.
7. Average dry weather flow of sewage in gallons per 24 hours.	1,310,000.
8. Gallons of sewage per head per day -	25·2.
9. Character of the sewage - - -	A very strong manufacturing sewage, containing a large quantity of wool scourings, etc. *
10. Period of observations - - -	November, 1902, to September, 1905.
11. Age of experimental Whittaker and Bryant filters.	Three years.
12. Amount of storm water treated during observations.	(1) *General Process.* Up to 6 million gallons per 24 hours are dealt with. (2) *Experimental Process.* The volume of septic tank liquor treated on the experimental filters is constant.
13. Total capacity of tanks in gallons -	(1) Precipitation tanks, 1,000,000. (2) Septic tanks, 200,000.
14. Total area of experimental filters in yards super.	400.
15. Total cubic content of experimental filters in yards cube.	1,200.

* The greater part of the sewage consists of slop-water, but a considerable number of water-closets and waste water-closets (900 water-closets and 540 waste water-closets) discharge into the sewers, and the sewers also receive about 70,000 or 80,000 gallons of trade refuse per day, made up of 14,000 gallons from Woolscourers, 50,000 gallons from Fellmongers, and 11,000 gallons from Rubber Recovery Works and Tripe Boilers.

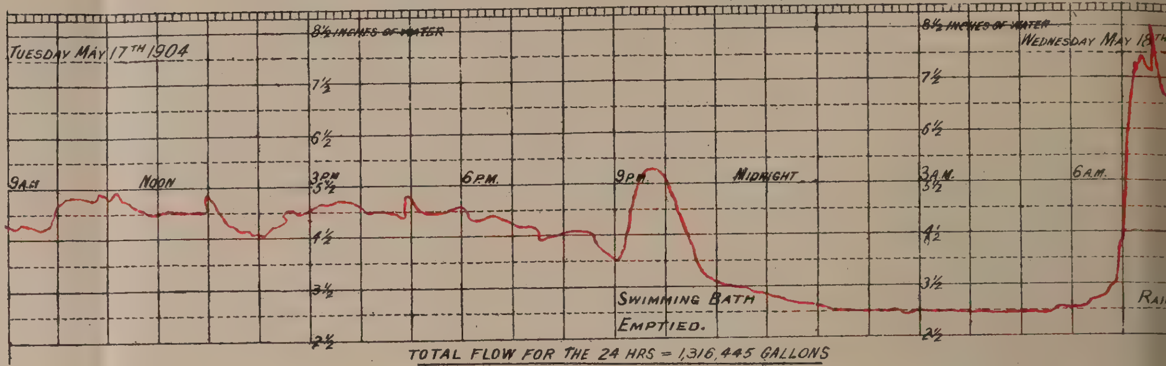
Diagram X.

Diagrams showing flow of Sewage at Rochdale as falling over a Weir 36" wide.

Note :- Over a Weir 36" wide

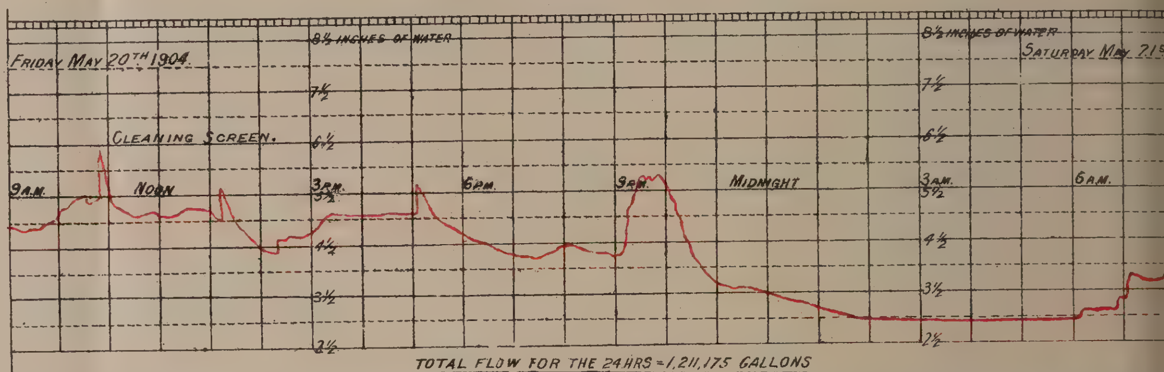
3·0 inches	a rate of	650,880 Gallons per 24 hours
4·0 "	" " "	1,000,800 " " " "
5·0 "	" " "	1,396,800 " " " "
6·0 "	" " "	1,843,200 " " " "
7·0 "	" " "	2,304,000 " " " "
8·0 "	" " "	2,822,400 " " " "
9·0 "	" " "	3,369,600 " " " "

Rainfall 0·05 inch.



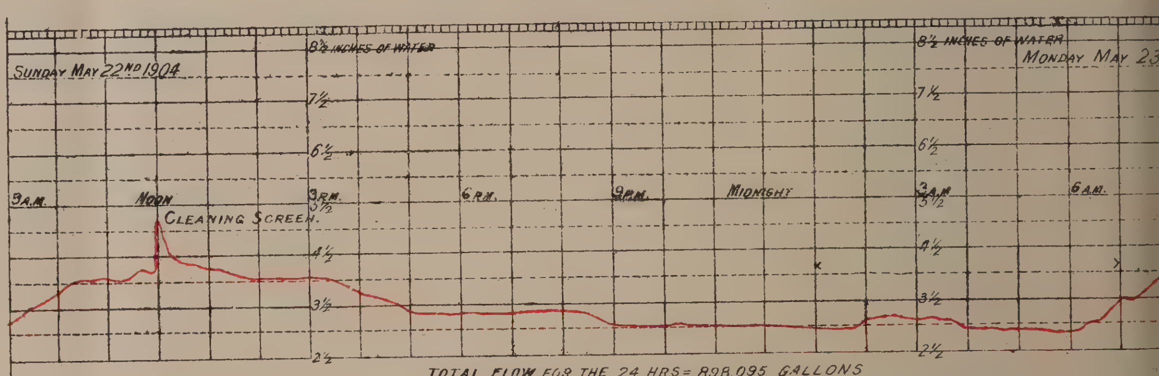
TOTAL FLOW FOR THE 24 HRS = 1,316,445 GALLONS

Dry day. Rainfall nil.



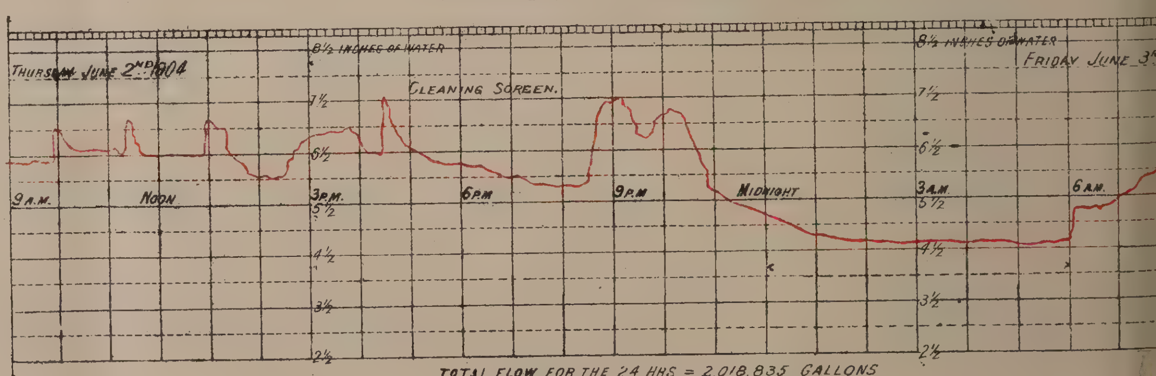
TOTAL FLOW FOR THE 24 HRS = 1,211,175 GALLONS

Dry Day. Rainfall Nil.



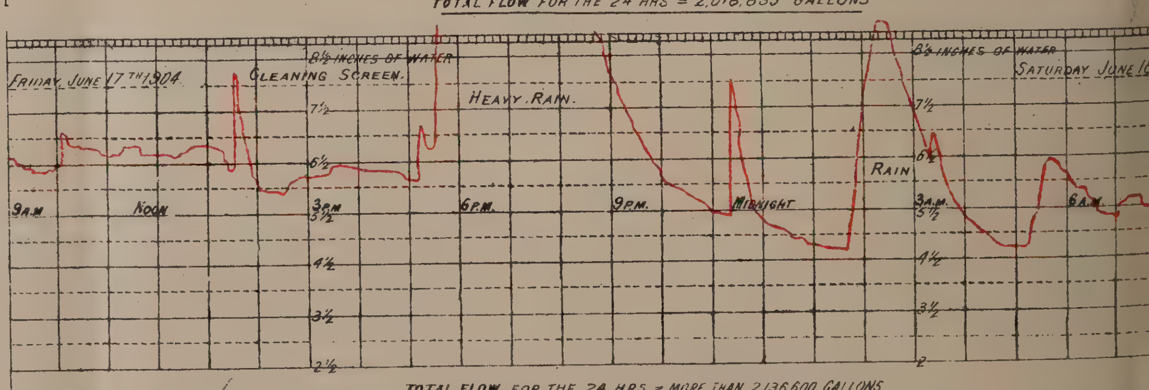
TOTAL FLOW FOR THE 24 HRS = 898,095 GALLONS

Dry Day. Rainfall Nil.



TOTAL FLOW FOR THE 24 HRS = 2,018,835 GALLONS

Rainfall 0·26 inch.



TOTAL FLOW FOR THE 24 HRS. = MORE THAN 2,136,600 GALLONS

5235. 06

Weller & Graham L.td Litho

16. Nature of filtering material - -	Coke, all pieces smaller than $1\frac{1}{2}$ inches being rejected.	
17. Gallons of septic liquor treated per yard super. per **24** hours (all filters included).	Nov. **1902** to Nov. **1903**, **400** Nov. **1903** to Apr. **1905**, **450** April **1905** to Sep. **1905**, **400**	Average, **424**.
18. Gallons of septic liquor treated per yard cube per **24** hours (all filters included).	Nov. **1902** to Nov. **1903**, **133** Nov. **1903** to Apr. **1905**, **150** April **1905** to Sep. **1905**, **133**	Average, **141**.
19. The final effluent is discharged into -	The river Roch.	

FLOW OF SEWAGE.

As the district is sewered upon the combined system, the greater portion of the rain falling upon the area finds its way into the sewers. The steep gradient of the old sewers, however, made it necessary to protect the three branch intercepting sewers by means of overflows, and a considerable portion of the storm-water is therefore diverted direct to the river.

There are in all fourteen overflows on the system, though only one of these is upon the main outfall sewer. The latter is capable of carrying sewage at the rate of about six million gallons per **24** hours and, as it occasionally runs full, this quantity is sometimes delivered at Roch Mills and there treated. Any excess above this amount is diverted by means of the storm overflows direct to the river. The maximum flow of six million gallons per **24** hours is equivalent to rather over four and a half times the dry weather flow to this outfall.

The sewage flow delivered by the Roch Valley sewer was measured continuously over a period of one month in May and June, **1904**, the second year of our observations. The first part of this period was dry and it was preceded by dry weather; we were thus enabled to form an approximate estimate of the dry weather flow, while the heavy rain which fell later gave opportunities for measuring the flow in wet weather.

The average daily flow during the first week of the gauging (including the **160,000** gallons treated by the Whittaker process) amounted approximately to **1,311,000** gallons per **24** hours, and this has therefore been taken as the dry weather flow.

During a period of seven wet days which occurred later, the average daily flow was approximately two million gallons per **24** hours.

In dry weather the flow is of a fairly even character, and it may be said to fall from a rather varying flow with a mean rate of about **2,000,000** gallons per **24** hours, which continues from **9** a.m. to **10** p.m., to a steady night flow at the rate of about **750,000** gallons per **24** hours.

The greatest day's flow of **1,350,000** gallons per **24** hours occurred on the Monday and Tuesday in the dry week mentioned above, and the lowest day's flow of **898,000** gallons per **24** hours came down on the Sunday.

In wet weather the variations in flow are large and rapid.

The average daily flow at Rochdale throughout the year **1904–5** was **1,992,000** gallons, or **52** per cent. above the dry weather flow. This figure was obtained by Mr. Platt, from hourly observations made at the works. Although not put forward as being strictly accurate, it is thought to give an approximate idea of the volume of sewage treated daily.

Subsoil Water.—It is known that some subsoil water enters the sewers, but the volume is not thought to be great.

On Diagram X are given some illustrations of the Sewage flow at Roch Mills.

Crude Sewage.—Three sets of hourly samples and three chance samples, were examined chemically. The hourly sets, Nos. 682, 689 and 690, were drawn over the usual three days, from May 16th to 19th, 1904, according to the rate of flow, the rainfall for these days being 0·0 inch, 0·05 inch and 0·04 inch respectively. Those samples may therefore be taken as very nearly representing the dry weather flow. No. 689 was noted as containing several lots of wool scourings, and no doubt this was present in the others also.

The chance sample of weakest night sewage, No. 696, which contained dye refuse, was drawn on Thursday, May 19th, 1904, at 3·30 a.m. Of the other two chance samples examined, No. 3,170, which contained much wool-scouring liquor and grease, was an early afternoon sample drawn in dry weather in June, 1903; while No. 3,317, also containing wool-scouring liquor, was taken in November of the same year at mid-day, in dry weather following wet. The following figures were obtained :—

Parts per 100,000.	Hourly Samples.		Weakest Night Sewage, No. 696.	Chance Samples.	
	Average.	Number of Estimations		No. 3170.	No. 3317.
Ammoniacal Nitrogen - - (4·04 to 4·25)	4·16	(3)	1·72	—	—
Albuminoid Nitrogen - - (1·17 to 1·42)	1·29	(3)	0·48	—	—
Total Organic Nitrogen - - (1·73 to 3·27)	2·60	(3)	1·01	—	—
Oxidized Nitrogen - - - - - -	0·0	(3)	Trace.	—	—
Total Nitrogen - - - (5·93 to 7·31)	6·73	(3)	2·75	—	10·81
"Oxygen absorbed" at 27° C. *at once* (8·55 to 9·18)	8·90	(3)	8·29	10·62	31·98
,, ,, at 27° C. *in 4 hours* (22·83 to 30·08)	26·55	(3)	12·05	51·56	66·35
Chlorine - - - - - (11·08 to 15·90)	13·01	(3)	11·44	—	13·30
Solids in Suspension - - (30·7 to *43·9)	36·70	(3)	2·80	134·4†	—
Solids by Centrifuge (vols.) - (195·0 to 339·0)	299·0	(3)	36·0	710·0	155·0
Ratio of Solids in Suspension to Centrifuge Solids - - - - -(1 : 6·3 to 1 : 9·6)	1 : 8·0	(3)	1 : 12·9	1 : 5·3	—

The above figures show the Rochdale sewage, as judged by the hourly samples, to be very strong, especially in oxidizable matter, as measured by the "oxygen absorbed" test, this being no doubt largely due to the fell-mongers' refuse, wool-scourings, and other manufacturing liquors present in the sewage. Pieces of floating fat were observed in the hourly set, No. 689. The three hourly sets contained practically equal quantities of ammonia, but they were not otherwise of very uniform composition. The sample of weak night-sewage was drawn at 3·30 a.m., and, although it had hardly any suspended solids, it was by no means weak as regards oxidizable matter; it contained brown-coloured dye-refuse and had a faint carbolic acid smell. Only a trace of nitrite was found in it, but, with so much oxidizable substance present, it does not follow from this that no subsoil water gains access to the sewers. The abnormally high figures given for "oxygen absorbed" from permanganate and for suspended solids by the chance sample, No. 3,170, are worthy of note; this sample contained much wool-scouring liquor and grease, and the solids were in large aggregates. The remaining chance sample, No. 3,317, also gave high "oxygen absorption" figures, but contained relatively few solids (say, about 20 parts), as judged by the centrifuge figure. Nothing more requires to be added, to emphasise the foul and greasy character of Rochdale sewage.

* This figure is possibly—though not probably—slightly in error.

† Containing 101·7 parts volatile on ignition.

Bacteriological Notes.—Three samples were examined bacteriologically. They yielded positive results with the B. coli and neutral red broth tests with ·00001 c.c. (100,000 per c.c.).

Description of the Samples.	Number of B. Coli (or gas-forming Coli-like Microbes).	B.S. = Bile Salt Glucose Peptone Test. N.R. = Neutral Red Broth Test. In. = Indol Test. L.P.M. = Lactose Peptone Milk Test.	B. Enteritidis Sporogenes test.	Remarks.
3170. Rochdale crude sewage, 17/6/03.	—	100,000 N.R.	100 not 1,000	
682. Rochdale crude sewage (screened), 17/5/04.	100,000 (+ indol) (+ clot)	100,000 N.R.	10 not 100	
689. Rochdale crude sewage, 18/5/04.	100,000 (+ indol) (+ clot)	100,000 N.R.	100 not 1,000	

SCREENS AND DETRITUS TANK.

Having passed through a 1½-inch screen, the sewage flows into a rectangular detritus tank, the four sides of which converge at the bottom. The heavy suspended matter, which settles here, is continuously lifted out by means of a bucket elevator driven by steam. The matter removed is tipped on the works.

It is from this catch pit that the sewage is taken for treatment by the septic tank and Whittaker-Bryant process, being lifted by means of a 4-inch pulsometer let down into the sewage. At this point, therefore, a small proportion of the sewage is diverted, while the rest flows through a second screen, with bars half-an-inch apart (this is raked by steam power), and then to the precipitation tanks.

EXPERIMENTAL OPEN SEPTIC TANK AND PERCOLATING FILTER PROCESS.

Intake.

The sewage which is treated in this experiment is taken from the catch-pit situated immediately in front of the outfall sewer. The sewage is therefore relieved of some portion of its grit and heavy detritus before entering the septic tank; it is delivered into a corner of the tank by means of a 3-inch delivery pipe from the pulsometer, and at a depth of 2 feet below the surface.

SEPTIC TANK.

Size - - - - - - - -	160 feet by 40 feet.
Depth of liquid - - - - - -	5 feet.
Capacity - - - - - - -	200,000 gallons.

Construction.—The septic tank is constructed of brick and cement walls, with a paved brick bottom resting on concrete. It is fitted with a floating arm for the purpose of drawing off supernatant liquor when it is being cleaned, and it has also one main sludge channel down the centre of the tank, which connects to an underground sludge culvert.

Except for two shallow scum-boards, which divide it into three equal parts, the tank is quite plain.

Flow Through.—With the normal flow of 160,000 gallons per 24 hours, the flow through the septic tank would be once in 30 hours, at the rate of 1·066 inches per minute.

Working.—The septic tank receives a constant quantity of sewage day and night, and it is only stopped for a short time twice a week, when the effluent tank is being cleaned out, and at the longer intervals when it is necessary to remove sludge from the septic tank itself.

The amount of sewage treated since the commencement of the experiment, in September, 1899, has varied as follows:—

September 1st, 1899, to December 1st, 1899	-	200,000 gallons per day.
December 1st, 1899, to March 7th, 1901 -	-	160,000 ,,
March 7th, 1901, to March 20th, 1901 -	-	200,000 ,,
March 20th, 1901, to November 15th, 1903	-	160,000 ,,
November 15th, 1903, to April 11th, 1905	-	180,000 ,,
April 11th, 1905, to September, 1905 -	-	160,000 ,,

Sludging.—The septic tank was started on September 1st, 1899, and ran till January 10th, 1902, before being cleaned out. During that time it received an average of 164,600 gallons of slightly settled sewage per day. At this first cleaning, after a run of 28⅓ months, 936 cube yards of sludge were removed and 193 tons of pressed cake were made from it.

Some difficulty was experienced in pressing this sludge, owing to the fact that it clogged the press cloths, and it was found necessary to add at least twice as much lime before pressing as is added at Rochdale to the sludge produced by chemical precipitation.

The quantity of sludge which had to be removed at this cleaning, the loss of tank capacity which its accumulation had involved, the difficulty of pressing the sludge, and the amount of suspended matter in the tank liquor seem to have led the authorities to clean the tank more often, and from this time up to 21st July, 1905, the sludge was removed periodically every 6 months. Since it was first started, the tank has been cleaned out 8 times, as follows:—10th January, 1902; 4th September, 1902; 21st April, 1903; 1st September, 1903; 13th April, 1904; 13th September, 1904; 8th March, 1905; and 21st July, 1905; during our observations, which extended from November, 1902, to September, 1905, the tank was cleaned out 6 times.

Some interesting calculations have been made by Mr. Platt, with regard to the respective amounts of sludge produced by chemical precipitation and by septic tanks.

From September 4th, 1902, to April 21st, 1903, 5·15 tons of pressed cake per million gallons were produced by the precipitation process, and 3·38 tons per million gallons by the septic tank process, which gives a saving of sludge production in the latter case of 35 per cent.

From April 21st, 1903, to September 1st, 1903, 4·21 tons per million gallons were produced by the precipitation process, as against 3·0 tons by the septic process—a saving in sludge production of 29 per cent.

From September 13th, 1904, to March 8th, 1905, 4·9 tons of sludge per million gallons were produced by the precipitation process, as against 3·6 tons per million gallons by the septic tank process, which gives a saving in sludge production of 27 per cent.

Mr. Platt puts these figures forward as being necessarily only approximate, but they are none the less important.

There has been no great nuisance caused during the operation of sludging the septic tank at Rochdale, the chief difficulty being that of pressing the sludge, and this has now been lessened by mixing the septic and precipitation sludges and pressing the two together. A large quantity of lime is however, necessary, even then.

The septic tank process is carried on continuously during the cleaning by utilising two adjoining tanks alternately; that is to say, when the septic tank requires to be sludged, the weir penstock (15 feet wide) in the division wall between the two tanks is opened at the end furthest from the inlet, the top liquor flows into the empty tank, and the pumping is continued until both the tanks are full. The penstocks are then closed and the pump delivery is changed to the recently filled tank, which now becomes the septic tank until the next cleaning; the previous septic tank, after it has been emptied, is utilised in the chemical precipitation treatment until again required for use as a septic tank. The plan of filling the new tank with the supernatant liquor from the old one appears to us to be a wise one, as it enables the process to go on without a break; we do not know of its having been carried out at any other place.

Septic Tank Liquor.—Three sets of hourly samples and seven chance samples were examined chemically. The hourly sets, Nos. 684, 687 and 692, were drawn at the same time as the hourly samples of sewage and of precipitation liquor, but in equal quantities per hour, because the Whittaker-Bryant filters treat a constant quantity throughout the day. They may, therefore, be taken as representing practically the dry weather flow.

They gave the following figures on analysis :—

———	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(3·70 to 3·76)	3·74	(3)
Albuminoid Nitrogen	(0·61 to 0·71)	0·67	(3)
Total Organic Nitrogen	(1·19 to 1·36)	1·27	(3)
Oxidized Nitrogen	-	0·0	(3)
Total Nitrogen	(4·89 to 5·12)	5·01	(3)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(4·49 to 6·19)	5·38	(3)
,, ,, ,, ,, ,, *in 4 hours*	(9·87 to 11·64)	10·92	(3)
Chlorine	(11·32 to 12·64)	11·97	(3)
Solids in suspension	(5·0 to 5·7)	5·30	(3)
Solids by centrifuge (vols.)	(27·0 to 31·0)	29·0	(3)
Ratio of solids in suspension to centrifuge solids	(1 : 4·27 to 1 : 6·2)	1 : 5·5	(3)

The above hourly sets of septic tank liquor were so similar in composition as to be almost identical. In the first two of them a smell of soap was still apparent. At the time when they were drawn the tank had been in use for only three months, and it will be noticed that the settlement of suspended solids was very good, only about 5 parts per 100,000 coming away in the liquor. Organically, however, this liquor is a strong one, both as regards nitrogenous and (especially) other oxidizable matter.

It is not, strictly speaking, correct to compare these hourly samples of septic tank liquor, drawn in equal quantities per hour, with the hourly samples of sewage, drawn according to rate of flow, but in view of the even composition of the samples of tank liquor, this comparison probably gives a fairly correct result. Subject to this proviso, we find the following reduction in figures in the septic tank liquor :—

Calculated on :—	Reduction.
Total Nitrogen	26 per cent.
Albuminoid Nitrogen	48 ,,
Total Organic Nitrogen	51 ,,
"Oxygen absorbed" *at once*	40 ,,
,, ,, *in 4 hours*	59 ,,
Solids in suspension	86 ,,
Solids by centrifuge (vols.)	90 ,,

From a chemical point of view, there was at the time a better separation of suspended solids in the septic than in the precipitation tank, and the precipitation liquor also gave rather a higher figure with the 4 hours "Oxygen absorbed" test. The total nitrogen in both was almost the same. We have no direct data as to the relative amounts of atmospheric Oxygen which the two liquors would require for complete oxidation, excepting the figures for permanganate oxygen absorption, already referred

to, and for dissolved Oxygen absorption in 24 hours by a chance sample of each liquor; but, judging from the degree of absorption of dissolved oxygen from water, over a period of two months, by some septic tank and precipitation liquors from other places, and bringing the results so obtained to bear upon the above figures of analysis, we should infer that the two liquors at Rochdale were of about the same organic strength, *i.e.*, that they would require about equal quantities of oxygen for their oxidation.

The seven *chance* samples of septic tank liquor examined, Nos. 3054, 3089A, 498, 3404A, 3463, 792 and 3668, were with one exception drawn in the cooler months of the year (November to March) and nearly all of them in dry weather. Though of course less uniform than the hourly samples, they were still, with two exceptions, comparatively even in composition, excepting as regards suspended solids, and were similar to the hourly samples. The following results were obtained :—

	Parts per 100,000.	Average.	Number of Estimations.
Total Nitrogen	(3·36 to 5·71)	4·40	(6)
Organic Nitrogen	(1·37 and 1·45)		(2)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(3·76 to 7·79)	5·12	(7)
,, ,, ,, ,, *in 4 hours*	(7·37 to 13·15)	10·20	(7)
Chlorine	(8·16 to 11·20)	9·69	(4)
Solids in suspension	(3·40 to 11·70)	8·60	(4)
Solids by centrifuge (vols.)	(25·0 to 54·0)	36·0	(7)
Ratio of solids in suspension to centrifuge solids	(1 : 4·3 to 1 : 9·1)	1 : 5·6	(4)

Sample No. 498 had 11·7 parts of suspended solids and No. 3668, 11·6 parts,—quantities far in excess of any of the others. No. 498 was drawn in March, 1903, after heavy rain, the tank having at that time been in use for 5 months; while No. 3668 was drawn in November, 1905, during a period of dry cold weather, when the tank had been running for only 4 months.

Averaged all together, these chance samples of septic tank liquor were slightly weaker than the hourly samples, excepting that they had rather more suspended solids. One sample was not noted for its reaction, but otherwise they were all alkaline and two of them had a tarry smell on the day of analysis.

Compared with the hourly samples of sewage, the chance samples of septic tank liquor show the following reduction in figures :—

Calculated on :—	Reduction.
Total Nitrogen	35 per cent.
"Oxygen absorbed" *at once*	42 ,,
,, ,, *in 4 hours*	61 ,,
Solids by centrifuge (vols.)	88 ,,

As a general rule, when a septic tank liquor is contrasted with a sewage in regard to the figures given by the "oxygen absorbed" from permanganate, the percentage reduction *at once* is about the same as that *in 4 hours*. But in the Rochdale samples of septic tank liquor, both chance and hourly, the percentage reduction *at once* was only two-thirds of that *in 4 hours*. This appears to suggest that the Rochdale liquor contains a good deal of organic matter, probably from manufacturing refuse, which is somewhat slowly oxidized; the point however, requires further investigation.

Bacteriological Notes.—Eight samples were examined bacteriologically. The B. coli and presumptive tests for B. coli, yielded positive results with from ·0001 c.c. to ·00001 c.c. (10,000 to 100,000 per c.c.). Four of the samples yielded positive results

with the B. enteritidis sporogenes test with ·01 c c. (100 per c.c.); the remaining four samples contained 10 spores of this anaerobe per c.c. Sample 3089A contained 990,000 microbes per c.c. (agar at 37°C.).

Description of the Samples.	Number of B. Coli (or gas-forming Coli-like Microbes).	B.S. = Bile-Salt Glucose Peptone Test. N.R. = Neutral Red Broth Test. In. = Indol Test. L.P.M. = Lactose Peptone Milk Test.	B. Enteritidis Sporogenes Test.	Remarks.
3054. Rochdale septic tank liquor, 19/11/02.	100,000 (– indol) (+ clot)	100,000 B.S. 10,000 not 100,000 N.R. 10,000 not 100,000 In. 100,000 L.P.M.	10 not 100	"Gas" test + ·1 c.c. (24 hours at 20° C·).
3089A. Rochdale septic tank liquor, 13/1/03.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R. 10,000 not 100,000 In.	10 not 100	Number of Bacteria (agar at 37° C.). 990,000 per c.c.
498. Rochdale septic tank liquor, 17/3/03.	100,000 (– indol) (– clot)	10,000 not 100,000 B.S. 10,000 not 100,000 N.R. 10,000 not 100,000 In.	100 not 1,000	
684. Rochdale septic tank liquor, 17/5/04.	100,000 (+ indol) (+ clot)	100,000 N.R.	10 not 100	
687. Rochdale septic tank liquor, 18/5/04.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R.	10 not 100	
692. Rochdale septic tank liquor, 19/5/04.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R.	100 not 1,000	
3463. Rochdale septic tank liquor, 6/6/04.	100,000 (– indol) (– clot)	100,000 B.S. 10,000 not 100,000 N.R.	100 not 1,000	
792. Rochdale septic tank liquor, 27/3/05.	10,000 not 100,000 (— indol) (– clot)	10,000 not 100,000 B.S. 10,000 not 100,000 N.R.	100 not 1,000	

PERCOLATING FILTERS.

Number - - - - -	2.
Size of each - - - -	48 feet diameter (octagonal).
Area of each - - - -	200 square yards.
Total area - - - -	400 square yards.
Depth of material - - -	9 feet.
Cubic content of each - -	600 cube yards.
Total cubic content - -	1,200 cube yards.
Material - - - - -	Gas coke above $1\frac{1}{2}$ inches diameter. (Note:—Generally speaking, it is a fairly coarse material, averaging probably 3 inches or 4 inches in diameter).

Construction.—On a concrete floor, which slopes in one direction, are laid perforated half pipes (18 inches diameter), raised on two courses of brick. The material rests upon these half-pipes, and for the first five feet, upwards, is held in position by wooden framing encircled by wire netting in the form of an octagon. Above this the sides of the filters slope in considerably towards the centre, so that for the upper part no framing is required. In the centre of each filter a circular chamber (4 feet 6 inches in diameter), built in pigeon hole brick-work, is carried up from the concrete floor. Its purpose is partly to allow of aeration and partly to carry the sprinkler.

Distribution.—On the top of the central chamber, a revolving sprinkler is fixed. This mechanism consists of four revolving arms constructed of iron pipes, perforated at varying distances with holes of varying size, so as to ensure a uniform distribution over the whole surface of the filter. The septic tank liquor is withdrawn from one corner of the septic tank at a depth of two feet below the water level, through a 5-inch pipe, and gravitates to a small wooden tank holding approximately 750 gallons. From this it is pumped by a 4-inch pulsometer, which raises the liquor and forces it into the sprinkler arms, causing the latter to revolve.

We understand that these now represent an old type of the Whittaker & Bryant sprinkler. The distribution they give, when worked in conjunction with a pulsometer, is very good, but in consequence of the running parts not being separated from the septic liquor flowing inside, a continuous leakage goes on at the pivot. The septic liquor, which has leaked out in this way, is collected again by a tray carried round the pivot and so taken back to the receiving tank; but this does not entirely do away with the defect, and splashes of tank liquor continually find their way into the filter effluent flowing over the concrete floor at the bottom of the central chamber.

The steam used in the pulsometer passes into the septic liquor, and has the effect of raising the temperature of it some 5°F. In the first winter of the experiment, an additional jet of steam was forced into the septic liquor, in order to raise its temperature still more; but, as it was afterwards found that the filters worked quite well in winter time without this additional heating, it was ultimately stopped.

Working.—Except for the two hours on two days a week when the effluent tank is being cleaned out, the filters receive septic tank liquor at a constant rate, continuously, day and night.

Age of Filters.—Both filters were first brought into use in September, 1899, and have not been altered in any way.

Amount of Septic Tank Liquor treated by the Filters.—The rate of filtration through the filters has varied slightly, as follows:—

September 1st, 1899, to December 1st, 1899	-	500 gallons per square yard per day.
December 1st, 1899, to March 7th, 1901	-	400 ,, ,, ,, ,,
March 7th, 1901, to March 20th, 1901 -	-	500 ,, ,, ,, ,,
March 20th, 1901, to November 15th, 1903	-	400 ,, ,, ,, ,,
November 15th, 1903, to April 11th, 1905	-	450 ,, ,, ,, ,,
April 11th, 1905, to September, 1905 ·	-	400 ,, ,, ,, ,,

During the observations, the rates of filtration have been as follows:—

November, 1902, to November 15th, 1903	-	400 gallons per square yard per day, or 133 gallons per cube yard per day.
November 15th, 1903, to April 11th, 1905	-	450 gallons per square yard per day, or 150 gallons per cube yard per day.
April 11th, 1905, to September, 1905 -	-	400 gallons per square yard per day, or 133 gallons per cube yard per day.

The average quantities treated during the observations have been:—

Per square yard per day	- - - - -	424 gallons.
,, cube ,, ,,	- - - - -	141 ,,

It will be seen that, on two occasions before the observations were begun, the rate of filtration was increased to 500 gallons per square yard per 24 hours. On both occasions, however, surface ponding took place in a short time, and the quality of the effluent fell off considerably. The Borough Surveyor concluded, therefore, that it was not advisable to work at this rate, and reverted to the old speed of 400 gallons per square yard per day. In view of this double experiment, we have not thought it necessary to ask the Authorities for permission to make any experiments with the flow, and have taken it for granted that it is not advisable to feed the filters with Rochdale septic liquor at a rate exceeding 400 gallons per square yard or 133 gallons per cube yard per day. The Borough Surveyor is of opinion, however, that the flow could be considerably increased during storms; though no such increase has in fact been made, the volume treated being practically constant.

Unsettled Effluents.—In addition to the samples of settled effluent, to be subsequently described, five samples of unsettled effluent were examined, viz., Nos. **3089B. 499, 3,464, 793** and **3,669.** Four of these were drawn in the cooler months of the year, and three in dry weather, and two in wet or after wet weather. They gave the following figures:—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - - - - -	(0·05 to 0·12 ap.)	0·08	(3)
Albuminoid Nitrogen - - - - - - - -	- (0·13 and 0·06)		(2)
Total Organic Nitrogen - - - - - - -	- (0·36 and 0·14)		(2)
Oxidized Nitrogen - - - - - - - - -	- (2·22 to 3·88)	2·76 ap. †	(5)
Total Nitrogen - - - - - - - - -	- (2·94 and 2·41)		(2)
"Oxygen absorbed" at 27°C. (80°F.) *at once* - - - -	- (0·23 to 0·96)	0·52	(5)
" " " " *in 4 hours* - - -	- (0·91 to 3·89)	2·56	(5)
Dissolved Oxygen taken up *in 24 hours* at about 18°C. -	(0·16 ap. to 0 66)	0·32 ap.	(5)
Incubator test (Scudder) - - - - - - - - -	practically,	* 5 passed	(5)
Incubator test (by smell) - - - - - - - -		* 5 passed	(5)
Smell when drawn - - - - - - - - - -		5 good	(5)
Smell when analysed - - - - - - - - -		5 good	(5)
Chlorine - - - - - - - - - -	- (7·96 to 10·00)	8·69	(3)
Solids in suspension - - - - - - - -	- (1·76 to 14·00)	7·39	(4)
Solids by centrifuge (vols.) - - - - - - -	- (25·0 to 141·0)	84·0	(4)
Ratio of solids in suspension to centrifuge solids - -	(1 : 10·1 to 1 : 14·3)	1 : 12·2	(4)
c.c. per litre Oxygen in solution - - - - - - - -	- (4·3 to 6·6 ap.)	5·4 ap.	(3)

Compared with the hourly and the chance samples of septic tank liquor, these effluents show the following reduction in figures:—

Calculated on:—	On Septic Tank Liquor.	
	Hourly Samples.	Chance Samples.
"Oxygen absorbed" *at once* - - - - -	92 per cent.	92 per cent. reduction
" " *in 4 hours* - - - -	87 "	86 " "
Solids in suspension - - - - - -	‡30 " approximate	§45 " approximate

As these unsettled effluents were—excepting for the quantity of suspended solids present in them—the same in character as the settled effluents dealt with later, nothing more need be said here than that they were in all other respects of the same high class.

Since, however, three of them were drawn at times corresponding to three of the settled effluents, a few of the comparative average figures of analysis may be given:—

———	Unsettled Effluents. Nos. 3089B, 3464, 793.	Settled Effluents. Nos. 3089C, 3465, 794.
"Oxygen absorbed" *at once* at 27°C. - -	0·62	0·46
" " *in 4 hours* - - -	2·55	1·56
Dissolved Oxygen taken up in 24 hours at about 18°C. - - - - - -	0·35	0·31
Solids by centrifuge (vols.) - - - -	97·0	54·0

* That No. 3,669 would withstand incubation was inferred. † Ap. approximately.

‡ Taking the average for the suspended solids in the effluents at 3·5 parts, calculated from the centrifuge figures.

§ Taking the suspended solids in the chance samples of septic tank liquor at 6·5 parts, calculated from the centrifuge figures.

In the above cases, therefore, the settlement of the solids effected at the works was only about 45 per cent. The comparatively low figures obtained for the absorption of dissolved oxygen in 24 hours are evidence that those solids are not of a readily putrescible character, *i.e.*, that the septic tank liquor has been well oxidized in its passage through the filters.

EFFLUENT SETTLING TANK.

Number - - - -	1.
Size - - - - -	23 feet 3 inches by 21 feet 6 inches.
Depth of water - - -	3 feet 3 inches.
Capacity - - - -	10,150 gallons.

Construction.—The effluent settling tank is constructed of brick and cement walls with a concrete bottom. It is covered over by boarding, in order to prevent the deposited sediment from fermenting and rising up through the liquid during hot weather.

The filter effluent flows into it over a long sill, extending the whole width of the tank, being delivered in a downward direction by means of a deep scum-board dipping down to within one foot of the bottom, close to the inlet sill. The effluent issues from the tank over another long sill extending the whole width of the tank, which is protected by a shallow scum-board. Otherwise the tank is of simple construction.

Flow through.—With the normal flow of 160,000 gallons per 24 hours, the flow through this tank would be once in 1·52 hours, at the rate of 3·05 inches per minute.

Working.—Except at those times when it is necessary to remove the matter which has settled in the tank, the flow is a continuous one.

Sludging.—The suspended matter from the filter effluent which settles in this tank is removed twice a week, the operation taking about two hours. It is carried out by first allowing the supernatant liquid to run off through a valve, situated 1 foot 9 inches from the bottom of the tank near the outlet end, and then pumping the remaining mixture of effluent and suspended matter back to the septic tank. No nuisance arises from the operation.

Effluents.

Settled Effluents.—Hourly Samples.—Three sets of hourly samples and eight chance samples were examined chemically. The hourly sets, Nos. 685, 688 and 693, which were of course drawn at the same time as the other hourly samples at Rochdale and, like the septic tank liquor, in equal fractions every hour, gave the following figures on analysis:—At this time the filters were treating 150 gallons of septic tank liquor per cube yard per 24 hours.

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - - - - -	(0·18 to 0·73)	0·47	(3)
Albuminoid Nitrogen - - - - - - - -	(0·10 to 0·15)	0·13	(3)
Total Organic Nitrogen - - - - - - - -	(0·48 to 0·53)	0·50	(3)
Oxidized Nitrogen - - - - - - - -	(1·81 to 2·63)	2·18	(3)
Total Nitrogen - - - - - - - -	(3·04 to 3·34)	3·15	(3)
"Oxygen absorbed" at 27° C. (80° F.) *at once* - - -	(0·41 to 0·66)	0·50	(3)
,, ,, ,, ,, *in 4 hours* - - -	(1·53 to 1·87)	1·68	(3)
Incubator test (Scudder) - - - - - - - - - -		3 passed	(3)
Incubator test (by smell) - - - - - - - - - -		3 passed	(3)
Smell when drawn - - - - - - - - - -		3 good	(3)
Smell when analysed - - - - - - - - -		3 good	(3)
Chlorine - - - - - - - - -	(10·96 to 11·46)	11·24	(3)
Solids in suspension - - - - - - - -	(2·3 and 2·0)		(2)
Solids by centrifuge (vols.) - - - - - - -	(27·0 to 30·6)	27·0	(3)
Ratio of solids in suspension to centrifuge solids -	(1 : 12·6 and 1 : 13·5)		(2)

In appearance the above effluents—apart from suspended matter—were clear, with a slight brownish tint. The suspended solids were very flocculent in character, so much so that their quantity appeared greater than it really was (2 to 2·5 parts per 100,000). All the samples had a clean smell, both when drawn and when analysed, and they all readily withstood incubation. They were fairly uniform in composition throughout. It will be noted that two thirds of the nitrogen present was in the form of nitrate (with almost no nitrite). The total organic nitrogen, relatively to the albuminoid nitrogen, was distinctly high, no doubt from the character of some of the organic trade refuse present in the sewage. The figures for "oxygen absorbed" from permanganate were fairly low.

As will be seen from the percentage reduction figures, given below, the reduction on the hourly samples of septic tank liquor was very good, though, as in the case of percolating filter effluents generally, the actual loss of nitrogen was moderate. The above effluents were thus of very good quality, and they were comparatively free from suspended solids.

Compared with the hourly samples of septic tank liquor and of sewage,* these effluents show the following reduction in figures —

Calculated on :—	Septic Tank Liquor.	Sewage.
Total Nitrogen	37 per cent. reduction.	53 per cent. reduction.
Albuminoid Nitrogen	81 " "	81 " "
Total Organic Nitrogen	61 " "	53 " "
"Oxygen absorbed" *at once*	91 " "	94 " "
" " *in 4 hours*	83 " "	94 " "
Solids in suspension	59 " approx.	94 " approx.
Solids by centrifuge (vols.)	9 " "	91 " "

Settled Effluents—Chance Samples.—Eight chance samples of settled effluent, Nos. **3055**, **3089c**, **3169**, **3318**, **3405b**, **3465**, **794**, and **3670**, were examined chemically. Two of them were drawn in the summer, but the other six in the cooler months of the year; and, again, two were drawn after wet, and the other six in dry weather. They gave the following results :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(0·05 to 0·11 approx.)	0·08 ap.	(3)
Albuminoid Nitrogen	(0·11 and 0·06)	—	(2)
Oxidized Nitrogen	(1·80 approx. to 3·58)	2·46 ap.	(8)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(0·22 to 0·66)	0·41	(8)
" " " " " *in 4 hours*	(0·95 to 2·42)	1·46	(8)
Dissolved Oxygen taken up in 24 hrs. at about 18° C.	(0·11 approx. to 0·61)	0·29 ap.	(8)
Incubator test (Scudder)		† 7 passed, 1 nearly passed	(8)
Incubator test (by smell)		† 8 passed	(8)
Smell when drawn		8 good	(8)
Smell when analysed		8 good	(8)
Chlorine	(7·34 to 10·06)	9·03	(4)
Solids in suspension	(2·60 to 6·70)	4·50	(3)
Solids by centrifuge (vols.)	(22·0 to 81·0)	45·0	(7)
Ratio of solids in suspension to centrifuge solids	(1 : 12·1 to 1 : 16·0)	1 : 13·5	(3)
Oxygen in solution (c.c. per litre)	(1·6 to 5·8 approx.)	4·2 ap.	(6)

* This comparison with the sewage is not strictly correct, the sewage having been drawn according to rate of flow, while the effluents were taken in equal quantities every hour.

† In one case it was assumed that the sample would withstand incubation.

In appearance and character these chance samples of effluent, as settled at the works, were the same as the hourly samples, *i.e.*, the liquid was clear and almost colourless (slightly brownish in tint), and the suspended matter was brown and very flocculent. They all had a perfectly clean smell, both when drawn and when analysed, took up very little dissolved oxygen from water in 24 hours, were fairly well ærated on the day of analysis, well nitrated, and readily withstood incubation. The average figure for "oxygen absorbed" from permanganate was 1·46 as against 1·68 in the hourly samples. Speaking generally, they were, for chance samples, of very even composition. In only one respect were these effluents at fault—they were not so well settled as they might have been. Judging from the centrifuge figures, the suspended solids in them averaged between 3 and 4 parts per 100,000, the highest figure obtained being 6·7 parts. One point is worthy of note here, viz., that in the case of samples Nos. 3,465 and 3,670, which were drawn within a few hours of the cleaning of the tank used for settling the suspended solids from the effluents, the settlement was not so good as the average. We think that the general conclusion to be drawn here is—that the settlement of effluent solids, on the system practised at Rochdale, can never be thorough, however clean the tank may be. Apart from the question of suspended matter, the effluents were of high class, and the purification of the septic tank liquor by the percolating filters was very satisfactory.

A few more comparative figures may be given in respect to six of the foregoing effluents, which were examined (*a*) with their contained suspended matter, and (*b*) after filtration through paper (4 samples) or settlement for two hours in the laboratory (2 samples). The numbers of these samples were :—

Unsettled - - - - - - Nos. 3,464, 793, and 3,669.
Settled - - - - - - Nos. 3,465, 794, and 3,670.

In every case the average of the six figures obtained is given.

Parts per 100,000.	(*a*)	(*b*)
"Oxygen absorbed" *at once* at 27° C. - - - - - - - -	0·57	0·30
,, ,, *in* 4 *hours* ,, - - - - - - - -	2·18	0·63
Dissolved Oxygen taken up *in* 24 *hours* at 18° C. - - - - - -	0·38	0·11
Solids by centrifuge (vols.) - - - - - - - - - -	85·0	4·0
Equal to suspended solids - - - - - - - - - -	6 to 7 parts	—

Here the difference in the figures obtained for the absorption of dissolved oxygen, and still more for the absorption of oxygen from permaganate, is very striking.

The absorption of dissolved oxygen by No. 3669 (unsettled) and No. 3670 (settled) was also determined for one and five days, both in the original and the paper-filtered samples, with the following results :—

Parts per 100,000.	No. 3669.			No. 3670.		
	Solids by Centrifuge.	Dissolved Oxygen taken up in		Solids by Centrifuge.	Dissolved Oxygen taken up in	
		24 hours.	5 days.		24 hours.	5 days.
Original sample - - - -	103·0	0·37	1·67	52·0	0·20	0·85
Paper-filtered sample - - -	—	0·08	0·09	—	0·03	0·32

In the original effluents containing suspended solids (roughly, about 8 parts in No. 3669 and 4 parts in No. 3670), the absorption of dissolved oxygen appears to have proceeded at practically the same rate for the five days, and not at an increased rate, a sign both of a good effluent and of well oxidised solids. In the filtered effluents the absorption of dissolved oxygen, even in five days, was very small—a further striking proof of the high degree of purity of the liquid portion of the Rochdale percolating filter effluents.

Bacteriological Notes.—Fifteen samples were examined bacteriologically. The results varied a good deal, but the best effluents yielded very good results. A considerable proportion of the samples yielded positive results with from ·01 c.c. to ·001 c.c. (100 to 1,000 per c.c.) with the B. coli and presumptive tests for B. coli. Sample 3,089B contained 27,000 microbes per c.c. As compared with sample 3,089A, this means a reduction of 97 per cent. The B. enteritidis sporogenes results were relatively less satisfactory. This has also been observed in connection with some percolating filters at other places.

Description of the Samples.	Number of B. coli (or gas-forming coli-like microbes).	B.S. = Bile salt glucose peptone test. N.R. = Neutral red broth test. In. = Indol test. L.P.M. = Lactose peptoue milk test.	B. enteritidis sporogenes test.	Remarks.
3,055. Rochdale Effluent, 19/11/02 (settled)	1,000 not 10,000 (– indol) (+ clot)	10,000 not 100,000 B.S. 10,000 not 100,000 N.R. 100 not 1,000 In. 1,000 not 10,000 L.P.M.	100 not 1,000	"Gas" test + 1 c.c. (24 hours at 20° C)
3,089B. Rochdale Effluent, 13/1/03 (unsettled)	100 not 1,000 (+ indol) (– clot)	Less than 100 N.R. 100 not 1,000 In.	10 not 100	Number of bacteria 27,000 (agar at 37° C.)
499. Rochdale Effluent, 17/3/03 (unsettled)	100 not 1,000 (+ indol) (+ clot)	100 not 1,000 B.S. 100 not 1,000 N.R. 100 not 1,000 In.	100 not 1,000	
3,169. Rochdale Effluent, 17/6/03 (settled)	—	100 not 1,000 N.R.	10 not 100	
3,318. Rochdale Effluent, 23/11/03 (settled)	10 not 100 (– indol) (– clot)	10 not 100 N.R.	1 not 10	
3,405B. Rochdale Effluent, 25/2/04 (settled)	—	Negative 100 N.R.	10 not 100	
685. Rochdale Effluent, 17/5/04 (settled)	100 not 1,000 (– indol) (– clot)	100 not 1,000 N.R.	10 not 100	
686. Rochdale Effluent, 18/5/04 (settled)	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R.	1,000 not 10,000	
690. Rochdale Effluent, 19/5/04 (settled)	100,000 (– indol) (– clot)	100,000 N.R.	1,000 not 10,000	
693. Rochdale Effluent, 19/5/04 (settled)	1,000 not 10,000 (+ indol) (+ clot)	1,000 not 10,000 N.R.	10 not 100	
694. Rochdale Effluent, 19/5/04 (unsettled)	10,000 not 100,000 (– indol) (– clot)	10,000 not 100,000 N.R.	10 not 100	
3,464. Rochdale Effluent, 6/6/04 (unsettled)	1,000 not 10,000 (– indol) (– clot)	1,000 not 10,000 B.S. 100 not 1,000 N.R.	100 not 1,000	
3,465. Rochdale Effluent, 6/6/04 (settled)	1,000 not 10,000 (– indol) (– clot)	1,000 not 10,000 B.S. 100 not 1,000 N.R.	10 not 100	
793. Rochdale Effluent, 27/3/05 (unsettled)	100 not 1,000 (+ indol) (+ clot)	100 not 1,000 B.S. 1,000 not 10,000 N.R.	100 not 1,000	
794. Rochdale Effluent, 27/3 05 (settled)	100 not 1,000 (– indol) (– clot)	Negative 100 B.S. 100 not 1,000 N.R.	100 not 1,000	

Effect of the Temperature upon the working of the Percolating Filters.—The temperatures of the atmosphere, of the septic liquor, and of the filter effluent have been taken by the Authorities four times a day since the installation commenced working in September, 1899. The averages of these temperatures over a period of two of the years included in our observations are as follows:—

——	Degrees.	
	F.	C.
Septic tank liquor as leaving tank	55·7	13·2
Septic tank liquor as falling from the sprinklers after pumping	60·8	16·0
Percolating filter effluent as leaving filters	55·8	13·2
Average maximum air temperature	55·2	12·9
Average minimum air temperature	44·2	6·8

During the two years mentioned above, the highest and lowest temperatures were as follows:—

——	Highest.	Lowest.
Septic tank liquor	66°F. June /02	42°F. Dec. 6 /04
Filter effluent	71°F. July /02	40°F. Dec. 6 /04
Atmosphere	92°F. July /02	16°F. Dec. 6 /04

GENERAL PROCESS.

Chemical precipitation and continuous flow subsidence, followed by treatment either upon land or upon double contact beds.

"ROUGHING"* TANKS.

Number	2.
Size of each	80 feet by 35 feet.
Working depth of water	6 feet.
Capacity of each	105,000 gallons.
Total capacity	210,000 gallons.

Construction.—The roughing tanks are constructed of brick and cement walls, with a concrete and paved brick bottom. They are fitted with floating arms and have one main sludge channel down the centre of each tank, which delivers to a sludge culvert below. The precipitated sewage, as it enters the tank through a wide penstock, is given a downward motion by means of a deep scum-board near the inlet end. It issues at the outlet end through an unprotected penstock.

Working.—The roughing tanks are used separately, each in turn receiving the whole flow, while the other is being sludged. Each tank is sludged once in from five to seven days.

Sludging.—Having removed the supernatant liquor by means of the floating arm, the sludge remaining at the bottom of the tank is pushed with squeegees through the sludge valve to the sludge culvert. From there it gravitates to a sludge sump, and is then lifted to the high level sludge tank. It is dealt with in the same way as the sludge from the other tanks, as described in a later part of this Report.

PRECIPITATION TANKS.

Number	5.
Size of each	160 feet by 40 feet.
Working depth of water	5 feet.
Capacity of each	200,000 gallons.
Total capacity	1,000,000 ,,
Total capacity of roughing tanks and precipitation tanks together	1,210,000 ,,

* The first two precipitation tanks at Rochdale are called "Roughing" tanks.

Construction.—The precipitation tanks are constructed of brick and cement walls, with a paved-brick bottom resting upon concrete. They are fitted with floating arms for the purpose of drawing off the supernatant liquid when sludging, and have also two shallow scum-boards, placed so as to divide each tank into three equal parts.

At each end of the tanks there is a wide channel, extending the whole width of the six tanks, by which the sewage enters and leaves each tank through unprotected penstocks; and, by an arrangement of penstocks in the channels, any one or more tanks may be thrown out of work, without interfering with the remainder. A special feature of the penstock arrangement at Rochdale is that, by raising by one foot the level of all the penstocks together (they are on the weir principle), the total tank capacity of the works can be increased by 275,000 gallons.

Precipitants.—The precipitants used are alumino-ferric and brown oil of vitriol, the latter being added on several days of the week to neutralise the alkali sent down by the wool-scourers. The sewage also receives a small amount of lime in the form of press-water.

The alumino-ferric is added in cages placed across the inlet channel between the grit-chamber and the roughing-tank, the sulphuric acid being dripped in from carboys subsequently; and the whole sewage is then mixed by moving mixers, driven by steam, as it flows along the channel to the roughing tank.

The following are the amounts of precipitant used during the years of observation:—

For the 12 months ending 31st March,	1904	-	Alumino-ferric, 202 tons.
,, ,, ,, ,,	,,	-	Vitriol, 159 tons.
,, ,, ,, ,,	1905	-	Alumino-ferric, 188 tons.
,, ,, ,, ,,	,,	-	Vitriol, 93 tons.

On the basis of the dry-weather flow, these quantities work out to an average of 7·3 grains of alumino-ferric and 4·7 grains of vitriol, per gallon of sewage.

Working.—The precipitation tanks are used in series, the sewage flowing first through the roughing-tank and then through the five precipitation tanks. As a rule, one roughing tank and five precipitation tanks are in use at one time The precipitation tanks are used in the regular order of 2, 3, 4, 5 and 6. Tanks Nos. 2, 3 and 4 are cleaned out every three to four weeks, and tanks Nos. 5 and 6 every five or six weeks.

Flow Through.—On the basis of an average daily flow of 1,992,000 gallons per 24 hours, the flow through the roughing tank and the five precipitation tanks generally in use would be once in 14·57 hours, at the rate of 12·07 inches per minute.

Sludging.—When it becomes necessary to remove the sludge from any one tank, this is cut out of the series, and after the supernatant liquor has been removed by means of a floating arm, the residual sludge is pushed with squeegees to the sludge culvert. The sludge culvert, common to all the tanks, carries it to the sludge sump, and from there it is lifted some 28 feet into an elevated sludge tank which commands the sludge mixer.

After a short period of settlement in this tank, given so as to allow of the separation of a further quantity of liquid, the sludge is passed into a mixer where a proportion of lime, equal to about 5 per cent. of the weight of pressed cake, is mixed with it, and the whole is then forced under pressure into one of the four presses in the press-house. As has been said previously, the press-water passes back into the main inlet channel, in front of the moving mixers.

The sludge from the three precipitation tanks used for the precipitation of the sewage collected in the Sudden Valley part of the Borough is also dealt with here, the two sludges being mixed in the elevated tank.

The amount of lime used for the pressing of both the precipitation and septic tank sludges, during the years ending 31st March, 1904 and 1905, was as follows:—

For the 12 months ending 31st March,	1904	- -	160 tons.
Do.	1905	- -	155 ,,

The amount of sludge cake produced was:—

For the 12 months ending 31st March,	1904	- -	3,380 tons.
Do.	1905	- -	3,200 ,,

The greater portion of the pressed cake is taken by local farmers, who are paid sixpence a load of not less than one ton ; the remainder is sold, carriage paid, to farmers in other agricultural districts. The average cost of disposal is sevenpence a ton.

Precipitation Liquor.—Hourly Samples.—Three sets of hourly samples and four chance samples were examined chemically. The three *hourly* sets, Nos. 683, 688 and 691, were drawn in May, 1904, according to the rate of flow of sewage, at the same time and under the same conditions of weather as the hourly samples of sewage. They gave the following results on analysis :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - - - - -	(3·68 to 4·50)	4·20	(3)
Albuminoid Nitrogen - - - - - - - -	(0·55 to 0·73)	0·66	(3)
Total Organic Nitrogen - - - - - - -	(0·80 to 1·19)	0·94	(3)
Oxidized Nitrogen - - - - - - - - - - -		0·0	(3)
Total Nitrogen - - - - - - - - - -	(4·85 to 5·34)	5·14	(3)
"Oxygen absorbed" at 27° C. (80° F.) *at once* - - -	(6·11 to 6·95)	6·40	(3)
,, ,, ,, ,, *in 4 hours* - -	(12·68 to 13·49)	13·17	(3)
Chlorine - - - - - - - - - - -	(11·70 to 13·98)	13·18	(3)
Solids in suspension - - - - - - - - -	(7·3 to 8·2)	7·80	(3)
Solids by centrifuge (vols.) - - - - - -	(20·0 to 26·0)	22·0	(3)
Ratio of solids in suspension to centrifuge solids - -	(1 : 2·5 to 1 : 3·2)	1 : 2·9	(3)

The above hourly samples of precipitation liquor were very uniform in composition. In appearance they were turbid, and they contained considerable amounts of finely divided (but, judging from the centrifuge figures, not very flocculent) suspended matter, were alkaline in reaction, and had a soapy smell. It will be seen that the precipitation effected was only moderate, the 37 parts of suspended solids in the sewage being reduced to 7·8 parts in the precipitation liquor. Compared with the hourly samples of sewage, we get the following reduction in figures :—

Calculated on :—	Reduction.
Total Nitrogen - - - - - - - - - - - - - - -	34 per cent.
Albuminoid Nitrogen - - - - - - - - - - - - -	49 ,,
Total Organic Nitrogen - - - - - - - - - - - -	64 ,,
"Oxygen absorbed" *at once* - - - - - - - - - - - -	55 ,,
,, ,, *in 4 hours* - - - - - - - - - - -	50 ,,
Solids in Suspension - - - - - - - - - - - - -	79 ,,
Solids by Centrifuge (vols.) - - - - - - - - - - - -	89 ,,

Chance Samples.—Of the four chance samples of precipitation liquor examined, Nos. 3,171, 3,316, 3,406 and 791, three were drawn in the colder months of the year. Two of them were taken in dry weather, and the other two in dry weather following wet. The two drawn in dry weather had almost the same composition as the hourly samples, judged by the "oxygen absorbed" test, while the other two were only about half as strong.

The following figures were obtained :—

	Parts per 100,000.	Average.	Number of Estimations.
Total Nitrogen - - - - - - - - - -	(2·18 to 4·96)	3·48	(3)
"Oxygen absorbed" at 27° C. (80° F.) *at once* - - -	(2·70 to 5·07)	4·03	(4)
" " " " *in 4 hours* - -	(5·88 to 13·07)	9·69	(4)
Chlorine - - - - - - - - - -	(7·08 and 10.46)	—	(2)
Solids in suspension - - - - - - - -	(3·5 and 8·5)	—	(2)
Solids by centrifuge (vols.) - - - - - -	(30·0 to 37·0)	34·0	(4)
Ratio of solids in suspension to centrifuge solids -	(1 : 9·4 and 1 : 4·2)	—	(2)

The above chance samples of precipitation liquor were therefore, as a whole, only about two-thirds as strong as the hourly samples. Two of them were noted as having a tarry smell, while No. 3,316, a dilute sample, had very little smell at all; this last is an indication of the entrance of subsoil water containing nitrate. The suspended solids were finely divided; if we are to judge by the centrifuge figures, they were present in greater quantities here than in the hourly samples, but the suspended matter in the Rochdale sewage appears to vary much in regard to flocculency, hence it would be unsafe to draw any conclusions on the point from those few samples. Sometimes acid is used in precipitation and sometimes not.

Bacteriological Notes.—Seven samples were examined bacteriologically. Generally speaking, the B. coli and presumptive tests for B. coli yielded positive results with from ·001 c.c. to ·0001 c.c. (1,000 to 10,000 per c.c.). As regards the B. enteritidis sporogenes test, two samples contained 1, two samples 10, and three samples 100 spores of this anaerobe per c.c.

Description of the Samples.	Number of B. coli (or gas-forming coli-like microbes).	B.S.=Bile salt glucose peptone test. N.R.=Neutral red broth test. In.=Indol test. L.P.M.=Lactose peptone milk test.	B. Enteritidis Sporogenes test.	Remarks.
3,171. Rochdale Precipitation liquor, 17/6/03	—	1,000 not 10,000 N.R.	1 not 10	
3,316. Rochdale Precipitation liquor, 23/11/03	1,000 not 10,000 (– indol) (– clot)	1,000 not 10,000 N.R.	100 not 1,000	
3,406. Rochdale Precipitation liquor, 25/2/04	1,000 not 10,000 (– indol) (+ clot)	1,000 not 10,000 N.R.	1 not 10	
683. Rochdale Precipitation liquor, 17/5/04	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R.	10 not 100	
688. Rochdale Precipitation liquor, 18/5/04	10,000 not 100,000 (– indol) (– clot)	10,000 not 100,000 N.R.	10 not 100	
691. Rochdale Precipitation liquor, 19/5/04	100,000 (– indol) (– clot)	100,000 N.R.	100 not 1,000	
791. Rochdale Precipitation liquor, 27/3/05	1,000 not 10,000 (– indol) (– clot)	1,000 not 10,000 B.S. 10,000 not 100,000 N.R.	100 not 1,000	

LAND AND CONTACT BED TREATMENT.

The precipitation liquors from both the Roch Valley and the Sudden Valley sewages are mixed together and treated either upon contact beds or upon land. Our observations have not extended to this part of the process, and we have taken no samples; but it may be stated that the greater part of the precipitation liquors in the day hours are treated upon the double contact beds, and the night precipitation liquors by intermittent downward filtration through land.

There are eleven contact beds, having a total area of 5½ acres (the land for which had previously been used for filtration), the primary beds being composed of clinker and ashes (4 inches to 1 inch diameter) 2 feet 9 inches deep, and the secondary beds of clinker (1 inch to a ¼-inch diameter) 3 feet 3 inches deep. The material is not graded.

All the contact beds are constructed by simple excavation. They are fed without distribution from a V-shaped sill.

On the average each primary bed is filled twice a day, and gives a contact of 4 hours.

The beds were all completed in 1903.

The total area of land is 91 acres, of which 41 are available as land filtration plots for the treatment of precipitation liquor. Three additional plots, having an area of 10 acres, are used for the treatment of crude sewage on Saturdays and Sundays, when trade refuse is practically absent from the sewage.

In general, the land is of an alluvial character, being mostly loam and gravel; but on the north side of the valley, where it begins to rise up from the flat, the soil is composed of stiff boulder clay. It is underdrained throughout, at the depth of 4 feet 6 inches, by 6-inch and 4-inch diameter socketted pipes, laid 10 yards apart. The main drains which carry the land effluent into the river Roch at 8 outlets consist also of socketted pipes. These vary from 9 inches to 18 inches in diameter.

SUMMARY.

The Roch Valley sewage at Rochdale is very strong, especially in oxidizable matter, as measured by the "oxygen absorbed" test, its strength being no doubt largely due to the wool-scouring and fellmongers' refuse which it contains. The water supply is only 18 gallons per head of the population, but, on the other hand, an appreciable quantity of subsoil water is known to enter the sewers.

The detritus tank is comparatively small, and removes only a small proportion of the grit from the sewage. It should, however, be borne in mind that where sewage is precipitated and the resulting sludge is pressed, as at Rochdale, the presence of grit appears to facilitate the pressing. Hence it is advisable in such cases not to carry the preliminary grit settlement too far.

At Rochdale various points of interest in connection with septic tanks have been arrived at independently by the Authorities, as the result of direct experiment, *e.g.*:—(1) That a strong and *very alkaline* sewage, whose chemical precipitation is an expensive process, is amenable to direct preliminary treatment in a septic tank, and that, with a 24 hours flow, the suspended solids in the tank liquor can be kept down to a reasonable figure, provided that the tank is sludged at intervals of from four to six months. (2) That the septic-tank sludge, however, is much more difficult to press than the precipitation sludge, and requires the addition of double the quantity of lime: by mixing the two sludges together, the pressing of the septic-tank sludge is much facilitated. (3) That there is a saving in sludge production of about 30 per cent. in the septic-tank process, as compared with the chemical precipitation process, and therefore also some saving of expense in pressing.

Another point of interest at Rochdale is that, when a septic tank is about to be sludged, the supernatant liquid from it is pumped into the alternative tank which is used in its place. In this way the "septic" process goes on without interruption.

Our own observations show that the settlement of suspended matter by the septic tank is good, with the tank worked in the manner just described. The hourly samples of septic-tank liquor examined contained an average of 5·3 parts, and four of the chance samples an average of 8·6 parts, of suspended solids per 100,000. Like the sewage itself, the tank liquor is organically strong; comparing the hourly samples of both, we find that the reduction in organic nitrogen effected by the septic tank was 51 per cent., and the reduction in oxidizable matter, as measured by the 4-hours "oxygen absorbed" test, 59 per cent. Of course, the conditions of working the septic tank at Rochdale are

very favourable, the flow through the tank being a constant one, whatever the volume and rate of the total flow of sewage may be.

The greater part of the sewage at Rochdale is precipitated by chemicals, but the precipitation effected is only moderate; the hourly samples of precipitation liquor showed **7·8** parts of suspended solids, as against **37** parts in the sewage. To bring about this reduction of about eighty per cent., some **12** grains per gallon of mixed precipitant have to be used, the solids being of a greasy and flocculent character. In other words, the sewage is a difficult one to clarify.

The average figures for total nitrogen in the hourly samples of precipitation liquor and of septic-tank liquor were almost the same, but the oxidizable matter—as measured by the **4** hours' "oxygen absorbed" test—was somewhat greater in the precipitation liquor. The general results of our analyses, however, taken along with the figures obtained for the absorption of dissolved oxygen by sewage liquids from other places, lead us to infer that the two liquors at Rochdale are of approximately the same organic strength, *i.e.*, that they would require about equal quantities of oxygen for their oxidation; possibly the precipitation liquor is rather the stronger of the two.

The Whittaker-Bryant filters at Rochdale were intended to be experimental. The construction is simple and comparatively inexpensive, and, though the wooden framework by which the material is kept in position is necessarily less durable than brick, it would, on the other hand, probably prove more convenient, if a filter had to be dismantled for the purpose of washing or renewing the filtering material The raising of the coke from the floor by means of a false bottom appears to be beneficial, by preventing any accumulation of sludge at the bottom of the filter, and thereby obviating the chance of any interference with the aeration of the filter and with the free passage of the liquid through it.

The large coke of which the filters are composed (over **1½** inches in size) does not appear to have disintegrated during the six years it has been in use, excepting where it has been trodden upon. Judging, too, from the quality of the effluent and from the fact that the filters have shown no serious signs of clogging, the size of the material is evidently well adapted for the purification of the tank liquor which it is called upon to treat.

The distribution of the tank liquor on to the filter is, generally speaking, very good, but as before remarked there is some leakage at the pivot. The arms of the sprinkler require to be cleaned out once a day, but this only takes a few minutes. The throb of the pulsometer undoubtedly tends to prevent choking of the holes in the sprinkler arms, and the raising of the temperature of the tank liquor by about **5**°F. is of course a material advantage. As against this, however, the expense of the pumping and the steam has to be placed.

The average volume of the strong septic tank liquor treated during the observations (November, **1902** to September, **1905**) was **424** gallons per square yard, or **141** gallons per cube yard per **24** hours. It was found by the Borough Surveyor that, when the volume was increased to **500** gallons per square yard, or **167** gallons per cube yard, the filters showed signs of ponding and the effluent fell off considerably in quality.

Apart from the suspended solids which they contained, the effluents were of high class, chemically speaking, the purification of the septic-tank liquor being very satisfactory. Bacteriologically, too, they showed a high percentage degree of purification—a noteworthy point, in view of the large size of the filtering material. The settlement of the solids in the effluent tank, through which there was a flow of once in two hours, was not at all times of the day very good. Although the hourly samples of settled effluent contained only about **2** parts, the chance samples had an average of **4·5** parts of suspended solids, as against **7·4** in the unsettled chance samples. Those solids being by themselves putrescible, though not very readily so, they might give rise to a nuisance if allowed to accumulate in the sluggish reaches of a stream.

Considerable smell arises during the sludging of both the precipitation and the septic tanks, and also in some degree from the sprinkling of the septic-tank liquor on to the filters. This is, of course, to be expected, when the nature of the sewage and the size of the tanks are taken into account.

No observations were made on the treatment by contact beds or by land, as this did not come into our scheme of work.

We cannot conclude this report without expressing our thanks to Mr. S. S. Platt, the Borough Surveyor, for the assistance which he gave us in our observations at Rochdale, and we are also much indebted to Mr. H. Ledson, the manager of the works.

SLAITHWAITE SEWAGE WORKS.

(Slaithwaite Urban District Council.)

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1. Situation of works - - - - - - -	About $\frac{1}{2}$-mile from the centre of the town.
2. Method of treatment - - -	Grit settlement and closed septic tanks, followed by filtration in single contact beds.
3. Population draining to works during observations - - - - - - -	3,000 (estimated average).
4 Water supply in gallons per head and whence obtained - - - - - - -	Amount not known; obtained partly from a catchwater reservoir and partly from Huddersfield Corporation. Both waters are of a soft character.
5. Number of W.C.'s connected - - - -	200.
6. Sewerage system - - - - - -	Partially separate.
7. Average dry weather flow of sewage in gallons per 24 hours - - - - - -	140,000.
8. Gallons of sewage per head per day - -	46·6.
9. Character of the sewage - - - - -	A dilute domestic sewage (mainly slop-water).
10. Period of observations - - - - -	November, 1902, to August, 1905.
11. Age of contact-beds - - - - -	4 years.
12. Amount of storm-water treated on the filters -	Not much more than the dry-weather flow is treated.
13. Total capacity of tanks in gallons -	80,464.
14. Total area of contact-beds in yards super -	439·1.
15. Total cubic content of contact-beds in yards cube - - - - - - - -	731·8.
16. Nature of filtering material - - - -	Furnace-clinker and ashes, obtained locally.
17. Gallons of septic liquor treated per yard super per 24 hours (all filters included) - -	103.
18. Gallons of septic liquor treated per yard cube per 24 hours (all filters included) - -	62.
19. The final effluent is discharged into - - -	The river Colne, which is polluted practically along its whole course.

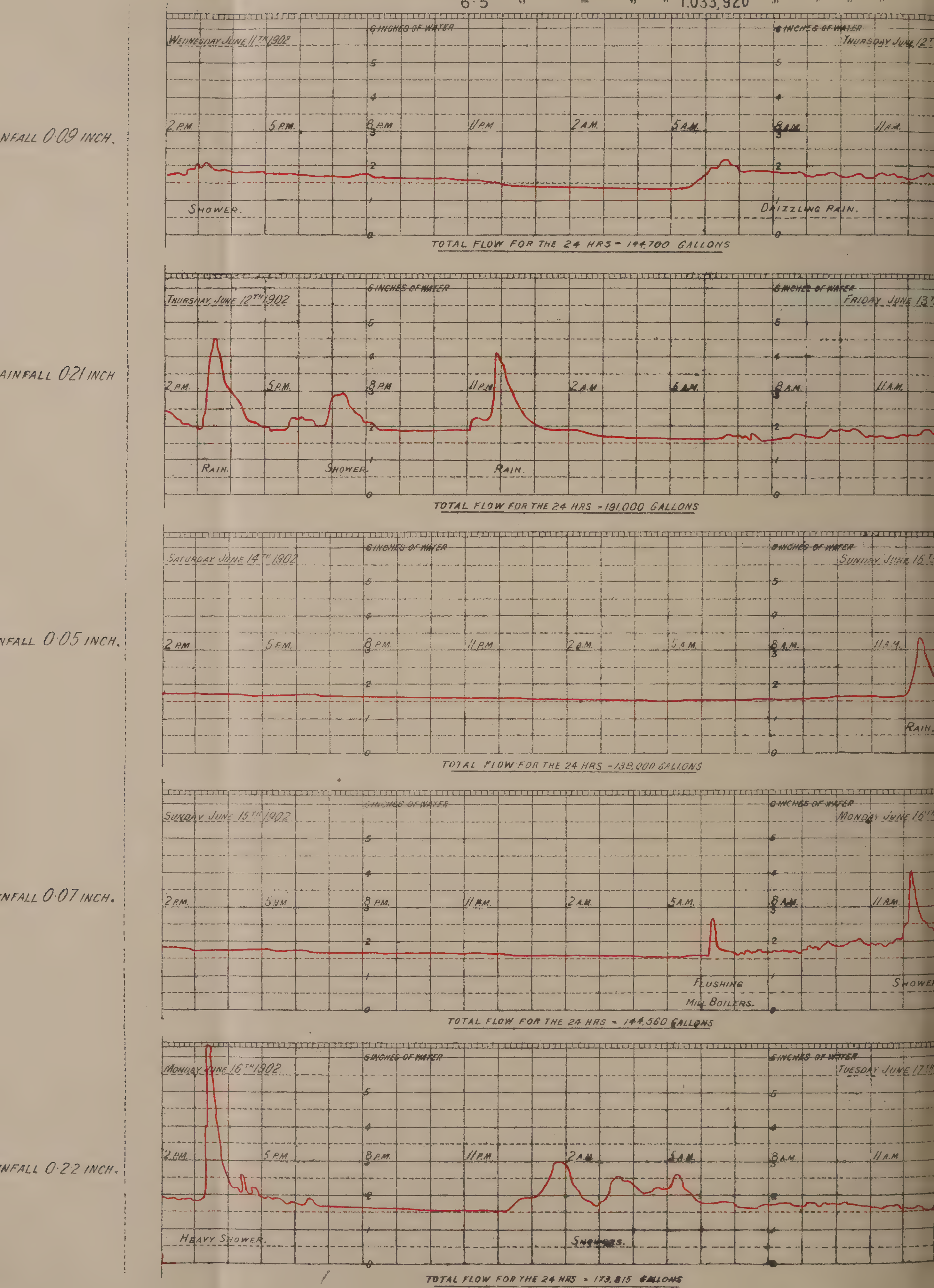
FLOW OF SEWAGE.

There is only one storm overflow on the Slaithwaite sewerage system, and as this is situated close to the works on the main sewer, the bulk of the surface water entering the sewers is brought to this point. Here, however, as the storm overflow is a large one, and capable of diverting the greater part of any flow exceeding about 800,000 gallons per 24 hours, not more than about five or six times the dry

Diagram Y.

Diagrams showing flow of Sewage at Slaithwaite as falling over a Weir 18" wide.

Note:- Over a Weir 18" wide	1·5 inches	=	a rate of	114,192	gallons per 24 hours.
	2·0 "	=	" "	176,400	" " " "
	3·0 "	=	" "	325,440	" " " "
	4·0 "	=	" "	502,560	" " " "
	4·5 "	=	" "	597,600	" " " "
	6·5 "	=	" "	1,033,920	" " " "



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weather flow reaches the sewage works. Of the storm water which goes forward from this overflow to the works, only a small proportion is filtered, the rest passing over additional overflows after settlement or treatment in the septic tanks.

The flow of sewage was gauged over a period of seven days in June 1902. Although practically dry weather prevailed for the first six of these days and the general weather which preceded was dry and warm, a considerable amount of rain fell in the previous week, and as the ground in the area still showed the effect of this, it is probable that the estimated dry weather flow obtained from the gaugings is rather high.

The average flow for the six dry days was approximately 140,000 gallons per day.

Owing chiefly to the relatively heavy night flow, which never fell below a rate of 100,000 gallons per day, and which is consequently indicative of the access of a large quantity of subsoil water to the sewers, the flow during the dry days was of an even character. Speaking generally, the sewage flow continued, with occasional fluctuations, at a rate of about 180,000 gallons per 24 hours from 10 a.m. to 4 p.m., while from midnight to 6 a.m. it flowed steadily at a rate of about 100,000 gallons per 24 hours. In times of rain the variations are very large, and increases of flow in the proportion of three to one within a quarter of an hour are common occurrences when anything like heavy rain falls upon the area. On one occasion, as the result of a heavy shower, an increase in the flow in the proportion of six to one within a quarter of an hour was recorded.

Subsoil Water.—A large quantity of subsoil water gains access to the sewers.

On Diagram Y are given some illustrations of the sewage flow at Slaithwaite.

Crude Sewage.—Three sets of hourly samples of crude sewage, Nos. 1, 2 and 3, and one chance sample, No. 3399, were examined chemically. The hourly samples were drawn in the middle of June, 1902, according to rate of flow, over 48, 72 and 48 hours respectively, *i.e.*, they represented a week's flow. The rainfall during the periods when the three sets were being drawn was 0·01 inch, 0·21 inch, and 0·29 inch. The second and third samples were thus considerably diluted by storm water and cannot be looked upon as representing the dry-weather flow; but as the district is a wet one, they probably approximate to the average daily flow throughout the year.

The chance sample, No. 3399, was drawn in dry weather on February 23rd, 1904, at 11 a.m.

The following results were obtained:—

Parts per 100,000.		Average.	Number of Estimations.	No. 3399.
Ammoniacal Nitrogen	(1·53 to 1·78)	1·66	(3)	0 77
Albuminoid Nitrogen	(0·35 to 0·45)	0·40	(3)	0·28
Oxidized Nitrogen		0·0	(2)	
Total Organic Nitrogen	(0·80 to 1·04)	0·89	(3)	?
Total Nitrogen	(2·50 to 2·58)	2·55	(3)	1·89
"Oxygen absorbed" at 27° C. (80° F) *at once*	(0·95 to 1·54)	1·18	(3)	1·06
,, ,, ,, ,, *in 4 hours*	(3·41 to 6·37)	4 60	(3)	6·06
Chlorine	(4·20 to 5·28)	4·77	(3)	
Solids in suspension	(3·36 to 20·10)	10·70	(3)	7·50
Solids by centrifuge (vols.)	(67·0 to 93·0)	76·0	(3)	51·0
Ratio of solids in suspension to centrifuge solids	(1 : 4·6 to 1 : 19·9)	1 : 10·8	(3)	1 : 6·8
"Cellulose" (by alkali, acid and ether)	(1·66 and 4·16)		(2)	
Ratio of cellulose to suspended solids	(1 : 5·2 and 1 : 4·8)		(2)	

The above samples had a bluish grey colour and a soapy smell, and excepting that No. 3 contained much more suspended solids, half of which was mineral matter, than either of the other two sets, they were all very uniform in composition. The heavy showers which fell on June 16th, and which accounted for most of the storm water in the third sample, was no doubt the cause of this rise in the suspended matter. The three figures for total nitrogen were practically identical. No. 3 was noted as containing much iron, probably from the cleaning out of the boilers at the dye works, etc., on Monday. The sewage at Slaithwaite is thus very dilute in every respect, although it is subject to considerable fluctuations as regards suspended matter.

The chance sample examined contained less nitrogenous matter than the hourly sets, but gave a higher figure for "oxygen absorbed" from permanganate. From internal evidence it probably contained some nitrate, which, however, was not tested for. A settlement in the laboratory for two hours reduced the suspended solids in this sample —which were of a coarse fibrous character—from 7·5 to 4·9 parts, while the centrifuge figure was lowered from 51 to 20, *i.e.*, to a relativety greater extent. The *finer* floating solid matter of the sewage was thus more compressible in the narrow centrifuge tube than the *whole* of the solids taken together—a point which is worth noting.

Bacteriological Notes.—Three samples of Slaithwaite crude sewage were examined bacteriologically. The results are considered under "Septic Tank Liquor."

Description of the Sample.	Number of B. coli (or Gas-forming Coli-like Microbes).	B.S. = Bile Salt Glucose Peptone Test. N.R. = Neutral Red Broth Test. In = Indol Test. L.P.M. = Lactose Peptone Milk Test.	B. Enteritidis Sporogenes Test.	Remarks.
1. Slaithwaite Crude Sewage. 12/6/02.	100,000 (+ indol) (+ clot)	100,000 B.S. 100,000 N.R. 100,000 In. 100,000 L.P.M.	100 not 1,000	"Gas" Test + ·01c.c. (24 hours at 20° C.)
4. Slaithwaite Crude Sewage. 15/6/02.	100,000 (+ indol) (+ clot)	100,000 B.S. 10,000 not 100,000 N.R. 10,000 not 100,000 In. 100,000 L.P.M.	100 not 1,000	"Gas" Test + ·01c.c. (24 hours at 20° C.)
7. Slaithwaite Crude Sewage. 17/6/02.	10,000 not 100,000 (+ indol) (+ clot)	1,000 not 10,000 B.S. 10,000 not 100,000 N.R. 10,000 not 100,000 In. 10,000 not 100,000 L.P.M.	100 not 1,000	"Gas" Test + ·01c.c. (24 hours at 20° C.)

GRIT TANKS.

Number - - - - - -	2.
Size of each - - - - -	About $17\frac{1}{2}$ feet by 4 feet.
Depth of water - - - - -	About 2 feet 3 inches.
Capacity of each - - - -	About 1,000 gallons.
Total capacity - - - - -	About 2,000 gallons.

These tanks are for the purpose of grit settlement and screening. They are each fitted with half-inch and quarter-inch screens, which are raked every day. The screenings are buried upon the works.

The tanks themselves are cleaned once a week, the matter removed being put into slop-carts and tipped.

SETTLING TANK.

(There was originally only one settling tank, but a second tank was completed and brought into use in 1904. As the great majority of the samples were taken when only one tank was in use, no further mention is made of the second tank in this report).

Size - - - - - - -	33 feet by 6 feet.
Depth of water - - - - -	About 5 feet 2 inches.
Capacity - - - - - -	6,394 gallons.

Construction.—The settling tank is constructed of brick and cement with a concrete bottom, and is covered in partly by boarding and partly by means of an asphalte roof carried on small iron girders. It contains "up and down" baffle walls every two feet of its length.

Working and Sludging.—While at work, the flow through the settling tank is a continuous one, but as the tank is used only in the daytime (9 a.m. to 5.30 p.m.), the flow is in reality intermittent. The deposit which settles in the tank is removed to a slop-cart twice a day, by means of a chain pump, without stopping the flow of sewage, and, having been mixed with street sweepings and gas lime, is given away to farmers.

SEPTIC TANKS.

Number - - - - -	3
Size of each - - - -	20 feet diameter and 21 feet deep.
Capacity of each - - -	26,821 gallons.
Total capacity - - - -	80,464 gallons.

Construction.—The septic tanks are constructed on the Dortmund plan, being cylindrical to a depth of about 10 feet and conical from there to the bottom.

The settled sewage is delivered into each at the top of the cone (i.e., at a depth of 10 feet), through a pipe carried down the centre of the tank.

The tank liquor issues through syphon pipes in the retaining wall which withdraw it at a depth of 18 inches below the water level. Each tank is covered with an asphalte roof which is carried on small iron girders.

Working.—The tanks are used in parallel for the treatment of the whole of the sewage.

Flow through.—On the basis of a dry weather flow of 140,000 gallons per day, the flow through each tank would be once in 13·6 hours.

Sludging.—No sludge has been removed from the septic tanks since they were first brought into use at the end of 1896, and they have therefore run without cleaning for a period approaching nine years. The protection from suspended matter, afforded by the settlement in the grit tanks, is, no doubt, one of the main reasons for this unusually lengthy run without sludging; but it seems probable also that, owing to the deep downward delivery, which no doubt prevents the tank becoming full of sludge, there has been established an equilibrium in each tank, and the amount of suspended matter issuing in the tank liquor approaches that which enters with the settled sewage. In any case, it will be seen that the settlement produced by the septic tanks is disappointing, and there is no doubt that it would have been better if the tanks could have been emptied occasionally. As they are fitted with sludge valves in the bottom of the cone, which connect to a sludge pipe brought to within 18 inches of the water level, sludge could be removed without emptying the tanks, and probably, therefore, the operation would not be a difficult one. On the other hand, it may be cheaper at Slaithwaite to occasionally renew the filtering material than to deal with septic sludge.

Septic Tank Liquor.—Three sets of hourly samples and 7 chance samples of septic tank liquor were examined chemically. The hourly sets, Nos. 2, 4 and 6, were drawn at the same time as those of the crude sewage, and also represented 48, 72 and 48 hours

respectively, or a total of one week's flow. As already explained with respect to the sewage, these samples do not represent the dry weather flow, but rather the average daily flow of all weathers. At the time that they were drawn the tank had been in use for 5½ years.

The following figures were obtained on analysis :—

	Parts per 10,0000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(1·67 to 1·93)	1·79	(3)
Albuminoid Nitrogen	(0·31 to 0·43)	0·37	(3)
Total Organic Nitrogen	(0·65 to 0·83)	0·74	(3)
Total Nitrogen	(2·41 to 2·76)	2·53	(3)
" Oxygen absorbed " at 27° C. (80° F.) *at once*	(0·85 to 1·42)	1·11	(3)
,, ,, ,, ,, *in 4 hours*	(3·10 to 4·52)	3·88	(3)
Chlorine	(4·80 to 5·40)	5·12	(3)
Solids in suspension	(6·40 to 7·50*)	7·10	(3)
Solids by centrifuge (vols.)	(37·0 to 54·0)	45·0	(3)
Ratio of solids in suspension to centrifuge solids	(1 : 5·0 to 1 : 8·4)	1 : 6·4	(3)
" Cellulose " (by alkali, acid and ether)	(1·26 and 2·48)		(2)
Ratio of " cellulose " to solids in suspension	(1 : 6·0 and 1 : 3·0)		(2)

The above three sets of tank liquor all had a distinct septic tank smell when analysed, and the sediment in them was dark grey to black in colour ; this sediment in No. 4 was noted as containing a very large number of animalculæ. In chemical composition they were on the whole very uniform, and much the same as the samples of sewage. The suspended solids in the tank liquor, however, unlike those of the sewage, did not fluctuate much in quantity during the week, and averaged 7·1 parts. This, though not in itself a high figure, was high relatively to the organic strength of the liquid portion. The septic tank liquor, therefore, which the filters had to treat in June, 1902, was a dilute one, though with more than a proportionate amount of matter in suspension.

Compared with the hourly sets of sewage, we find the following reduction in figures:—

Calculated on :—	——
Albuminoid Nitrogen	8 per cent. reduction.
Total Organic Nitrogen	9 ,, ,,
Total Nitrogen	0 ,, ,,
Ammoniacal Nitrogen	+ 8 per cent.
" Oxygen absorbed " *at once*	7 ,, ,,
,, ,, *in 4 hours*	16 ,, ,,
Solids in suspension	34 ,, ,,
Solids by centrifuge (vols.)	41 ,, ,,
" Cellulose " in solids	36 ,, ,,

* Estimated indirectly.

Chance Samples.—The 7 chance samples of septic tank liquor examined, Nos. 3,049, 3,098A, 512, 3,268A, 3,400, 3,458 and 3,531, were drawn between November, 1902, and August, 1904, all of them excepting the two last in the cooler months of the year. The tank had been in use for 6 years when the first sample was taken, and for 7½ years when the last came to be drawn. The samples were for the most part dry weather ones.

The following results were obtained:—

Parts per 100,000.		Average.	Number of Estimations.
Ammoniacal Nitrogen	(0·82 to 2·08)	1·44	(3)
Albuminoid Nitrogen	(0·32 to 0·38)	0·35 *	(3)
Total Nitrogen	(1·90 ap. to 2·90)	2·42	(4)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(0·51 to 1·80)	1·14	(7)
" " " " *in 4 hours*	(1·56 to 6·50)	4·04	(7)
Chlorine	(1·84 to 4·76)	3·48	(6)
Solids in suspension	(7·0 to 15·0)	9·70	(4)
Solids by centrifuge (vols.)	(16·0 to 64·0)	39·0	(7)
Ratio of solids in suspension to centrifuge solids	1 : 4·2 to 1 : 7·3	1 : 5·8	(4)

Five of the above samples were noted as having a septic tank smell, and two of them a soapy smell when analysed; the solids were for the most part black, and in a fine state of division. It will be seen that while, on the average, these chance samples of septic tank liquor had much the same chemical composition as the hourly ones, the variations in quality were much greater. The weakest sample, by far, was No. 3,268A, drawn in October, 1903; for three days previously the weather had been dry, but prior to that there had been a very wet week, and no doubt the ground water still continued to leak into the sewers in large quantity, which had in the meantime been well washed out. The strongest sample was the one last examined, No. 3,531, drawn in August, 1904, in dry, hot weather, though there had been a heavy shower three hours before the sample was taken. It will be observed that the suspended solids in this sample had risen to 15 parts, half of which was mineral matter; it was thus evident that the tank required sludging.

No. 3,531 was partially examined both before and after filtration through paper, and the comparative figures of analysis are interesting, thus:—

Parts per 100,000.	Original Sample.	Filtered through Paper.
"Oxygen absorbed" at 27° C. *at once*	1·80	0·74
" " " *in 4 hours*	6·50	3·12
Dissolved Oxygen taken up in 24 hours at about 19° C.	5·27	4·80
Solids in suspension	15·0	—
Solids by centrifuge (vols.)	64·0	—

From the fact that nearly as much dissolved oxygen was taken up from water in 24 hours by the paper-filtered as by the original sample, it looked as if the suspended solids present did not take it up with much avidity, in other words, that they were well digested; it would be unwise, however, to attempt to draw any deduction from a single observation.

* Possibly a little too high.

Compared with the hourly samples of sewage, these chance samples of septic tank liquor show hardly any reduction in figures, *e.g.*—

Calculated on—	Reduction.
Oxygen absorbed *at once* - - - - - - - - - -	4 per cent.
„ „ *in 4 hours* - - - - - - - - - - - -	12 „

This small reduction is, no doubt, partly due to the large quantity of sludge which had accumulated in the septic tank. Their analysis confirms what was said with regard to the hourly samples, viz., that the septic tank liquor at Slaithwaite is a dilute one organically, but that during our observations the filters had a disproportionately large amount of suspended matter put upon them.

Bacteriological Notes.—The samples of Slaithwaite crude sewage and tank-liquor yielded positive results with the B. coli test and presumptive tests for B. coli with ·0001 c.c. to ·00001 c.c. (10,000 to 100,000 per c.c.). The B. enteritidis sporogenes test usually gave a positive result with ·01 c.c. (100 per c.c.). Samples 3,049 and 3,098A of septic tank-liquor contained 4,500,000 and 2,900,000 bacteria per c.c., respectively.

Description of the Sample.	Number of B. Coli (or Gas-forming Coli-like Microbes).	B.S. = Bile-salt Glucose Peptone Test. N.R. = Neutral Red Broth Test. In. = Indol Test. L.P.M. = Lactose Peptone Milk Test.	B. Enteritidis Sporogenes Test.	Remarks.
2. Slaithwaite septic tank liquor, 12/6/02.	10,000 not 100,000 (+ indol) (— clot)	10,000 not 100,000 B.S. 10,000 not 100,000 N.R. 10,000 not 100,000 In. 100,000 L.P.M.	1,000 not 10,000	"Gas" test + ·01 c.c. (24 hours at 20° C.)
5. Slaithwaite septic tank liquor, 15/6/02.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 B.S. 10,000 not 100,000 N.R. 10,000 not 100,000 In. 100,000 L.P.M.	100 not 1,000	"Gas" test + ·01 c.c. (24 hours at 20° C.)
8. Slaithwaite septic tank liquor, 17/6/02.	10,000 not 100,000 (+ indol) (+ clot)	100,000 B.S. 100,000 N.R. 10,000 not 100,000 In. 10,000 not 100,000 L.P.M.	100 not 1,000	"Gas" test + ·01 c.c. (24 hours at 20° C).
3049. Slaithwaite septic tank liquor, 17/11/02.		—	100 not 1,000	Number of bacteria 4,500,000 per c.c. (agar at 37° C.)
3098A. Slaithwaite septic tank liquor, 11/2/03.	100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R. 100,000 In.	100 not 1,000	"Gas" test + ·01 c.c. (24 hours at 20 C.) Number of bacteria 2,900,000 per c.c. (Gelatine at 20° C.)
3268A. Slaithwaite septic tank liquor, 19/10/03.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R.	1 not 10	
3458. Slaithwaite septic tank liquor, 5/5/04.	100,000 (+ indol) (+ clot)	100,000 N.R.	100 not 1,000	
3531. Slaithwaite septic tank liquor, 9/8/04.	100,000 (— indol) (— clot)	100,000 B.S. 100,000 N.R. 100,000 In. 100,000 L.P.M.	100 not 1,000	

CONTACT BEDS.

(NOTE.—Two additional contact beds were constructed during 1903 and 1904, and first brought into use towards the end of the observations in 1905. As no observations were made upon them, they are not included here.)

Number - - - - - - -	4.
Size of each - - - - -	40 feet 4 inches by 24 feet 6 inches.
Area of each - - - - -	109·78 square yards.
Total area - - - - -	439·1 square yards.
Depth of material - - -	5 feet.
Cubic content of each - - -	182·97 cube yards.
Total cubic content - -	731·8 cube yards.
Material - - - - - - -	Furnace clinker and ashes, graded as follows:— Top: 1 foot—$\frac{3}{8}$ inch to $\frac{1}{2}$ inch diameter. Middle: 3 feet—$\frac{3}{8}$ inch to 1 inch diameter. Bottom: 1 foot—above 1 inch diameter.

Construction.—Brick and cement walls with concrete bottoms.

Distribution (1902, 1903 and 1904).—The distribution on the contact beds is effected by means of two wooden troughs laid on the surface of the material. These are fed from a main trough carried across the centre of the beds.

Underdraining.—Ten lines of three-inch agricultural pipes, each connecting to a main six-inch drain which leads to the valve chamber.

Age of Beds.—The beds were first used in 1898.

Working.—The beds are filled in turn with septic tank liquor from 9 a.m. to 4 p.m. each day. They rest during the night and also on Sundays.

Except during wet weather, the number of fillings given to each bed per day is almost constant. At the beginning of the observations, in the last half of 1902, the number of fillings averaged 1·7 per day for each bed; in March and April 1905—just before the two new beds were brought into use—it was 1·66. The average number of fillings throughout the whole period, including all rests, was 1·5 per day.

The period of contact, however, has grown gradually less. As the plan of working was to allow the tank liquor to remain in one bed until the next bed had been filled, it depended upon the rate of filling and the water capacity of the beds. At the commencement of the observations a contact of two hours was usually given, but towards the end it averaged about one hour.

Capacity.—The original empty tank capacity of the four beds, when filled to the depth of the filtering material, was 123,510 gallons. The original water capacity, therefore, assuming the material when new to occupy half the space of the tank, was 61,755 gallons.

Soon after the commencement of the observations in 1902, a first measurement of capacity was made by gauging bed No. 1. Taking the capacity of this bed to be typical of the others also, the total capacity at this time was approximately 33,600 gallons, or 54·4 per cent. of the original estimated water capacity and 27·2 per cent. of the original empty tank capacity. At this time, therefore, after working at an average rate of about 1½ fillings per day for four years, the capacity of the beds was by no means exhausted, and they still retained 27 per cent. of their original empty tank capacity.

The winter of 1902 was rather a wet one at Slaithwaite, and although the rate of working the beds was only slightly accelerated, the increased rate of flow through the septic tanks—which were then six years old—brought more suspended matter on to the surface of the filters. As a result of this, the beds gradually deteriorated in appearance, and by February, 1903, seemed to be so clogged and sodden that it was thought necessary to make another gauging. Bed No. 1, therefore, was re-gauged on February 11th, 1903. The result was surprising, for it gave an estimated total capacity of 32,640 gallons, or still 52·8 per cent. of the original water capacity. The beds, therefore, were not so bad as they appeared to be on the surface. That the surface itself was in a serious state, however, is undoubted, for from this time the beds could only be filled with difficulty, and by the end of April in the same year they had become so clogged that streaming was resorted to; on June 3rd they had to be stopped altogether. A rest of nearly three months was given, and at the same time the top six or eight inches of the material on all the beds were removed and replaced with a similar layer of new ashes.

On August 26th, 1903, the treatment was restarted, and, after the beds had received one filling a day (Sunday excluded) until October 12th, in order to make sure that they had quite recovered, the original rate of working ($1\frac{1}{2}$ fillings per day) was again resorted to.

This experience is especially interesting in showing that in some cases where fairly fine material is used on the surface of contact beds, a clog does not necessarily extend throughout the whole of the material.

As no further difficulty in the working occurred, it was not thought necessary to repeat the gauging until the end of the observations in September, 1905.

On May 8th, 1905, the two new beds mentioned above were brought into use, and at the same time the top foot of material in No. 2 old bed was removed and replaced with new clinker. All four old beds at this time showed the effect of the winter's work, and we understand that it is the intention of the Authorities to renew the upper part of the material in them. But No. 2 bed, owing probably to the fact that it had always leaked badly, and had therefore received more sewage during its lifetime than it should have done, was considerably worse than the other three.

From May 8th to September 1st 1905, the three remaining old beds received on an average ·5 filling per day.

On September 1st the capacity of No. 1 bed was again measured. If it is assumed that No. 2 bed had still been in use and in approximately the same condition as the others, the total capacity as shown by this gauging would be about 28,000 gallons, or 45·3 per cent. of the original estimated water capacity, and 22·6 per cent. of the original empty tank capacity.

After receiving, therefore, on the average between $1\frac{1}{2}$ and 2 fillings per day, for rather more than seven years, one of the four beds has had to be partially renewed and the other three are approaching what has been considered to be the limit of economical working.* During this time the surfaces of the beds once got into a very clogged state, and the top few inches of the material had to be removed and renewed, while the beds were given a thorough rest; but otherwise the working has continued with only periodical digging and raking over.

Amount of Septic Tank Liquor treated by the Contact Beds.—The average number of fillings given to each of the four beds during the whole of the observations has been 1·5 per day, and the mean water capacity has been roughly 30,000 gallons. On this basis, therefore, the amount treated has been as follows:—

Per square yard per 24 hours - - - - - -	103 gallons.
Per cube yard per 24 hours - - - - - -	62 gallons.

* Note—February 1906. The top foot of material on each of the beds has now been removed and replaced, and the beds are stated to be in good order again.

Effluents.—Ten chance samples of effluent were examined chemically, of which seven were ordinary samples drawn at mid-flow after 1 hour's contact*, while the remaining three were experimental samples. The seven ordinary samples, Nos. 3051, 3098C., 513, 3269B., 3398, 3460 and 3532, were drawn at intervals between November, 1902, and August, 1904, and at hours varying between 9.15 a.m. and 5 p.m., mostly in dry or fairly dry weather, and five out of the seven in the cooler months of the year.

They gave the following results on analysis .—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(0·51 to 1·21)	0·84	(3)
Albuminoid Nitrogen	(0·13 to 0·22)	0·17	(3)
Total Organic Nitrogen	(0·35 to 0·52)	0·45	(3)
Oxidized Nitrogen	(0·0 to 1·1 ap.)	0·57	(7)
Total Nitrogen	(1·59 to 2·03)	1·84	(5)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(0·27 to 1·29)	0·59	(7)
" " " " " *in 4 hours*	(0·70 to 3·89)	2·15	(7)
Dissolved Oxygen taken up in 24 hours at 18°C.	(0·44 to 3·01 ap.)	1·52	(5)
Incubator test (Sudder)	3+, 2−		(5)
Incubator test (by smell)	2+5−		(7)
Smell when drawn	6+1−		(7)
Smell when analysed	6+1 (?)		(7)
Chlorine	(3·50 to 4·44)	3·95	(5)
Solids in suspension	(6·0)		(1)
Solids by centrifuge (vols)	(1·4 to 52·0)	17·0	(7)
Ratio of solids in suspension to centrifuge solids	(1 : 8·8)		(1)
	c.c. per litre		
Oxygen in solution	(0·0 to 3·1)	1·1	(4)

In appearance these effluents varied somewhat, but they may be described generally as opalescent and containing but small quantities of suspended matter. Indeed, if we exclude the last sample examined, No. 3532, which was drawn in the month of August in hot weather and shortly after a very heavy shower, and which contained nearly as much matter in suspension as all the other six samples put together, the effluents were very free from matter in suspension. Calculated from the centrifuge figures, the suspended solids would average about 2 parts in the whole seven effluents, or about $1\frac{1}{4}$ parts in the first six. Chemically, the effluents were fairly uniform in composition, so far as total nitrogen was concerned.

Six out of the seven effluents had a clean smell when drawn, the seventh being soapy, while six had also a clean smell on the day of analysis, one being marked as suspicious in this respect. The oxidized nitrogen averaged about 0·6 part and constituted one-third of the total nitrogen present. As only two out of the seven withstood incubation† (though two others almost did so), it is obvious that the purification had not been carried far enough to produce an effluent of high quality, and this is further borne out by the absorption of dissolved oxygen, the average figure for this being 1·5 (in five estimations, including, however, the last-drawn sample).

* Nos. 513 and 3532 had contacts of $\frac{3}{4}$ and $1\frac{1}{2}$ hours respectively.

† Reversing the incubation results of 3098B. and 3098C., which had evidently been accidentally transposed.

The above effluents can thus only be described as of very moderate quality, the reduction in the oxidizable matter of the septic tank liquor—as measured by the "oxygen absorbed" test—being about 50 per cent., and the reduction in the suspended solids about 70 per cent.

Compared with the hourly and chance samples of septic tank liquor, we find the following reduction in figures (the figures in brackets indicate the number of estimations):—*

Calculated on :—	Septic Tank Liquor: Percentage reductions.	
	Hourly Samples.	Chance Samples.
Total Nitrogen	27 (5)	42 (3)
Albuminoid Nitrogen	54 (3)	51 (3)
Total Organic Nitrogen	39 (3)	21 (4)
Oxygen absorbed *at once*	47 (7)	48 (7)
" " *in 4 hours*	45 (7)	47 (7)
Suspended solids (calculated approximately from the centrifuge figures	70 ap. (7)	70 ap. (7)

Experimental Effluents.—Three experimental samples of effluent were drawn for comparison with three of the ordinary chance samples, already described, and their figures of analysis may be given here in detail. The reasons for drawing them will be stated afterwards.

Parts per 100,000.	Sample No.					
	3050	3051	3098B.	3098C.	3459	3460
Ammoniacal Nitrogen					1·21	1·21
Albuminoid Nitrogen					0·23	0·22
Total Organic Nitrogen					0·43	0·35 †
Oxidized Nitrogen	0·92	0·92	0·50 ap.	1·10 ap.	0·39	0·33
Total Nitrogen	2·05	2·03	2·07	1·89	2·03	1·89 †
"Oxygen absorbed" at 27° C. *at once*	0·59	0·62	0·84	0·33	0·50	0·50
" " " *in 4 hours*	2·22	2·26	2·46	1·34	1·98	1·85
Dissolved oxygen taken up in 24 hours at 18° C.	‡0·33	‡0·44			1·04	0·98
Incubator Test (Scudder)	+	+			—	
Incubator Test (by smell)	—	—			Just —	Just —
Smell when drawn	+	+	+	+	?	+
Smell when analysed	+	+	+	+	+	+
Chlorine	4·00	4·05	2·10	3·50	4·28	4·44
Solids by centrifuge (vols.)	12·0	13·0	77·0	19·0	17·0	20·0
c.c. per litre Oxygen in Solution	2·3	3·1			0·0	0·0

* In nearly every case the chance samples of septic tank liquor and of effluent were drawn to correspond with one another.
† These two figures may be a trifle too low.
‡ At laboratory temperature.

Nos. 3050 and 3051 were from the same emptying, No. 3050 being made up of a number of fractions of the effluent, taken roughly according to the rate of flow every 10 minutes during the 80 minutes which the bed required to empty itself, while No. 3051 was a single sample drawn at mid-flow. The figures of analysis show the two samples to have been identical, that is to say, the sample taken at mid-flow gave a true average of the whole emptying.

No. 3098B was a first flush, while 3098C was a mid-flow sample from the same emptying. The results as regards incubation are contradictory, and it looks as almost certain that the incubation figures have been accidentally transposed, though the records do not show this; in the summary of the effluent analyses, they are taken as having been transposed. Leaving this point out of account, it is seen that the first flush of liquid contained four times as much suspended solids as the mid-flow sample (judged by the centrifuge figures), and that its figure for "Oxygen absorbed" in 4 hours was nearly twice as high as the other.

No. 3459, from Bed No. 3, was only given one-half hour's contact, while No. 3460, from Bed No. 2, had a contact of one hour, the same tank liquor being treated in each case. It will be seen, from the figures of analysis, that there was practically no difference between the two. So, assuming the beds to have been in the same condition at the time (they appeared to be so), the longer period of contact had affected practically no further purification. From the measurements of capacity, bed 3 was probably in rather the better condition, hence the value of the above results is to some extent lessened, although we do not think materially so.

A word or two may be added with regard mainly to the absorption of dissolved Oxygen by effluents Nos. 3460 and 3532, both of them mid-flow samples.

Some of the figures of analysis may be given first:—

———	No. 3460.	No. 3532.	
		Original.	Filtered through paper.
Oxidized Nitrogen	0·33	0·0	
Incubator Test (by smell)	Just —	—	—
"Oxygen absorbed" at 27° C. *at once*	0·50	1·29	0·64
" " " *in 4 hours*	1·85	3·89	2·29
Dissolved Oxygen taken up in 24 hours at 18°C.	0·89 (72 hours 3·29)	3·0 + x	1·34
Solids in suspension		6·0	
Solids by centrifuge (vols.)	20·0	52·0	

As has already been seen, No. 3460 was an effluent which just failed to withstand incubation. The quantity of dissolved Oxygen which it took up in three days was rather more than three times the figure for one day, but not very much more.

No. 3532, already noted as a sample of poor quality, contained an unusual amount of suspended solids (6·0 parts). The power of those solids of absorbing dissolved Oxygen is very strikingly shown here, for, whereas the original effluent took up more than 3 parts in 24 hours, the effluent freed from its solids took up 1·34 parts.

Bacteriological Notes.—Thirteen samples were examined bacteriologically. With two exceptions all the samples yielded positive results with the B. coli test and presumptive tests for B. coli with from ·0001 c.c. to ·00001 c.c. (10,000 to 100,000 per c.c.). Samples 513 and 3,269B both yielded negative results with ·0001 c.c. (less than 10,000 per c.c.). As regards the B. enteritidis sporogenes test, three samples contained 1, four samples 10, and the remaining six samples 100 spores of this anaerobe per c.c. Samples 3,050, 3,051, 3,098B and 3,098C contained 127,000, 262,000, 2,800,000, and 1,200,000 microbes per c.c. respectively.

Samples 3,050 and 3,051 represented, respectively, an average sample made up of fractions collected during the whole process of emptying and a sample collected at mid-flow (*i.e.*, half way through the emptying).

Samples 3,098B and 3,098C represented, respectively, the first flush on emptying the bed and the mid-flow.

Description of the Sample.	Number of B. coli (or gas-forming Coli-like Microbes).	B.S.=Bile Salt Glucose Peptone Test. N.R.=Neutral Red Broth Test. In.=Indol Test. L.P.M.=Lactose Peptone Milk Test.	B. Enteritidis Sporogenes Test.	Remarks
3. Slaithwaite Effluent, 12/6/02.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 B.S. 10,000 not 100,000 N.R. 10,000 not 100,000 In. 10,000 not 100,000 L.P.M.	100 not 1,000	"Gas" test + ·1 c.c. (24 hours at 20°C.).
6. Slaithwaite Effluent, 15/6/02.	10,000 not 100,000 (+ indol) (+ clot)	100,000 B.S 10,000 not 100,000 N.R. 1,000 not 10,000 In. 10,000 not 100,000 L.P.M.	10 not 100	"Gas" test − ·1 c.c. (24 hours at 20°C.).
9. Slaithwaite Effluent, 17/6/02.	10,000 not 100,000 (− indol) (− clot)	10,000 not 100,000 B.S. 10,000 not 100,000 N.R. 10,000 not 100,000 In. 10,000 not 100,000 L.P.M.	100 not 1,000	"Gas" test + ·01 c.c. (24 hours at 20°C.).
3,050. Slaithwaite Effluent, 17/11/02.	—	—	100 not 1,000	Number of bacteria 127,000 per c.c. (agar at 37°C.).
3,051. Slaithwaite Effluent, 17/11/02.	—	—	10 not 100	Number of bacteria 262,000 per c.c. (agar at 37°C.).
3,098B. Slaithwaite Effluent, 11/2/03.	100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R. 100,000 In.	100 not 1,000	"Gas" test + ·1 c.c. (24 hours at 20°C.). Number of bacteria 2,800,000 per c.c. (Gelatine at 20°C.).
3,098C. Slaithwaite Effluent, 11/2/03.	100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R. 100,000 In.	100 not 1,000	"Gas" test + ·1 c.c. (24 hours at 20°C.). Number of bacteria 1,200,000 per c.c. (Gelatine at 20°C.).
513. Slaithwaite Effluent, 1/4/03.	—	1,000 not 10,000 N.R. 1,000 not 10,000 L.P.M.	10 not 100	
3,269B. Slaithwaite Effluent, 19/10/03.	1,000 not 10,000 (+ indol) (− clot)	1,000 not 10,000 N.R.	1 not 10	
3,398. Slaithwaite Effluent, 23/2/04.	100,000 (+ indol) (+ clot)	100,000 N.R.	1 not 10	
3,459. Slaithwaite Effluent, 5/5/04.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R.	1 not 10	
3,460. Slaithwaite Effluent, 5/5/04.	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R.	10 not 100	
3,532. Slaithwaite Effluent, 9/8/04.	100,000 (+ indol) (+ clot)	100,000 B.S. 100,000 N.R. 100,000 In. 100,000 L.P.M.	100 not 1,000	

Effect of temperature upon the working of the beds.—Without experience of severe weather during the observations at Slaithwaite, we are able to say little as to the probable effect of such weather upon the beds. The observations upon temperature, however, which included measurements made on the occasion of each visit to the works and also a complete set of measurements taken every few hours throughout a week in June, 1903, indicate that the effluent takes its temperature from that of the sewage and is only slightly affected by the temperature of the atmosphere. It is probable, therefore, that only such conditions as would tend to lower the temperature of the sewage—rapidly melting snow, for instance—would affect the working of the beds to any degree.

SUMMARY.

The Slaithwaite sewage is a very dilute one in every respect, although it is subject to considerable fluctuations as regards suspended matter, these fluctuations being due to the hilly nature of the district and to the consequent rapid rises in volume of the sewage caused by rain; in the three sets of hourly samples examined, the suspended solids varied between 3·4 and 20·1 parts per 100,000. The dilute character of the sewage arises mainly from the large quantity of subsoil water which gains access to the sewers. The climate of Slaithwaite being a rather wet one, large flows both of subsoil and of surface water are of frequent occurrence.

The septic tanks receive the sewage after it has undergone preliminary settlement in a grit chamber, followed by one small settling tank,*—a method which in this case, at all events, is correct in principle and at the same time inexpensive, since both of these settling chambers can be readily cleaned out. There appears, too, to be no difficulty in disposing of the sludge so obtained. The beneficial effect of this preliminary settlement is, however, largely discounted at Slaithwaite by the fact of the septic tanks not being cleaned out periodically. When our observations came to an end, in August, 1905, the tanks had been in use for seven and a half years without having ever been sludged. This is all the more to be regretted, as Slaithwaite is the only place where we have had the opportunity of observing a Dortmund tank in use* as a septic tank; hence we are unable to describe, from actual experience, the working of a septic tank of this shape, and the extent to which it frees the sewage from the suspended solids, when only a moderate quantity of sludge is allowed to accumulate in it.

Owing to the facilities which a tank of the Dortmund form offers for periodical sludging, we think that it has in this respect a distinct advantage over the ordinary rectangular tank, and especially if the avoidance of nuisance during sludging is a serious consideration. A deep circular tank is also easier and cheaper to cover than a (relatively) shallow rectangular one, occupying as it does less surface area; but on the other hand it is, as a rule, more expensive to construct.

The disadvantage of allowing sludge to go on accumulating as it did at Slaithwaite is evident from the fact that the hourly samples of septic tank liquor (drawn after the tank had been in use for 5½ years) contained 7·1 parts of suspended solids; this, though not a high figure in itself, is disproportionate when the dilute character of the liquid is taken into account. Chemically speaking, the hourly samples of septic tank liquor showed very little difference in composition from the hourly samples of sewage. On the other hand, the method of working the septic tank followed at Slaithwaite results in having comparatively little sludge to deal with, at the expense of loss of capacity in the beds.

The construction of the filter tanks presents no unusual features, but the very small cost of the filtering material—a mixture of furnace clinker and ashes—is worthy of note; this cost only 1/- per cubic yard in position in the beds. Provided such material does not disintegrate rapidly, the utilization of a local waste product of little money value is a point in favour of the use of contact beds for treating the sewage of a small community. Material of this nature, if it were to be used for percolating filters, would require to be much more carefully selected, because clogging in a percolating filter is more difficult to remedy than in a contact bed.

The small size of the fragments of filtering material constituting the upper layers had the effect of maintaining the capacity of the beds by largely preventing suspended matter from percolating into them. The beds continued in regular use for four years

* There are now two such tanks (January, 1906).

at $1\frac{1}{2}$ fillings per day and, with one renewal of the uppermost few inches of material, they lasted for seven years, by which time the gaugings showed that their capacity had sunk to 22 per cent. of the original empty tank capacity. One bed had then to be partially renewed, and the authorities were considering the renewal of the top foot of material in all the others. The filtering material appeared to have disintegrated to some extent, but not so much as its origin might have led one to expect.

Excepting that they contained on the average only about 1 to 2 parts of suspended solids, the effluents examined were but of indifferent quality, chemically and bacteriologically, being for the most part putrescible upon incubation, although they had a clean smell both when drawn and on the day of analysis; in other words, their oxidation had not proceeded quite far enough. A little further treatment would have enabled them to pass any reasonable standard of purity, but at present the treatment of the dilute sewage at Slaithwaite, on the lines followed there, and with $1\frac{1}{2}$ fillings per bed per day, is insufficient to produce a thoroughly satisfactory effluent. Had the suspended solids been better separated from the tank-liquor before it was run on to the beds, and had the filtering material in the lower parts of the beds been of smaller size, we think that the effluents would have shown a distinct improvement in qualtiy.

The stream into which the effluent discharges was during the time of our observations too much polluted to allow of our drawing any useful deductions from the admixture of effluent with the water.

From the experimental samples of effluent examined, the following points of interest were brought out (the second is, of course, already well known):—

(1) That the middle portion of the discharge of effluent from a contact-bed represents, chemically, a fair sample of the whole discharge;

(2) That the first flush of a discharge contains an altogether disproportionate amount of suspended matter.

We have never been conscious of any serious nuisance from smell during our visits to the works at Slaithwaite, and think that this absence of smell is due to three reasons:—

(1) Because of the dilute character of the sewage;

(2) Because the sludge from the settling-tanks is removed, while still comparatively fresh, by means of a chain-pump working under water, and is then taken away from the works in a covered slop-cart;

(3) Because the septic tanks are covered in.

We should like, in conclusion, to express our thanks to Mr. C. Gledhill, Clerk to the Slaithwaite Urban District Council, Mr. Hiram Sykes, the Surveyor, and Mr. James Whitehead, Chairman of the Sewage Committee, for much assistance in connection with our work at Slaithwaite.

WITHNELL SEWAGE WORKS.

(WITHNELL URBAN DISTRICT COUNCIL).

1. Situation of Works - - - - - -	About $1\frac{1}{2}$ miles from the centre of the district sewered.
2. Method of treatment - - - - - -	(1) Chemical precipitation and quiescent subsidence, followed by continuous filtration through sand and polarite, with final treatment upon land (10,000 gallons per day). (2) Double contact of crude sewage, with final treatment upon land (5,000 gallons per day).
3. Population draining to Works during observations.	1,650 (estimated average).
4. Water supply in gallons per head, and whence obtained.	11. Liverpool Corporation (Rivington Moor supply, a fairly soft water).
5. Number of W.C.'s. - - - - -	About 26.
6. Sewerage system - - - - - -	Partially separate.
7. Average dry-weather flow in gallons per 24 hours.	15,000.
8. Gallons of sewage per head per day - -	9.
9. Character of the sewage - - - -	A very strong domestic sewage
10. Period of observations - - - - -	November, 1902, to October, 1905
11. Age of beds - - - - - - -	Contact beds, $2\frac{1}{2}$ years; Polarite filters, 2–8 years.
12. Amount of storm water treated at Works -	Not more than 3 or 4 times the dry-weather flow is treated.
13. Total capacity of tanks in gallons - - -	32,312.

	Contact beds.	*Polarite filters.*
14. Total area of beds in yards super - - -	135.	83·2.
15. Total cubic content of beds in yards cube -	196·1.	90·0.
16. Nature of filtering medium - - - -	Clinker.	Sand, polarite and gravel.
17. Gallons of sewage treated per yard super per 24 hours (Note—all filters included).	26·4.	68·6.
18. Gallons of sewage treated per yard cube per 24 hours.	18·2.	63·5.
19. The final effluent is discharged into - -	The Roddlesworth Brook.	

FLOW OF SEWAGE.

The inclusion of back roof and yard water results in large increases of flow at the sewage works during wet weather. There is only one storm overflow on the system; this is situated upon the main sewer, and diverts some of the storm-water direct to the Whave Brook, where it causes obvious pollution at such times. As it is set so as to come into operation at about 3 times the dry weather flow, it may be taken that not more than 3 or 4 times the dry weather flow ever passes to the works for treatment.

The flow of sewage was measured continuously over a period of 7 days in July, 1904. A small quantity of rain (0·1 of an inch) fell upon the first day and had the effect of increasing the flow slightly for a short time; but as the weather, both before and after this, was perfectly dry, the dry weather flow estimate obtained from the gaugings may be taken as being fairly accurate.

The average daily flow from Friday, July 15th, to Thursday, July 21st, was 15,000 gallons per 24 hours, and this has, therefore, been taken as the dry weather flow.

The highest day's flow (17,000 to 20,000 gallons per 24 hours) occurred on the Monday and Thursday of the week, while the lowest (13,300 gallons per 24 hours) took place on the Sunday.

In dry weather the flow is of a fairly even character, the variation being a fairly gradual fall from a rate of about 18,000 gallons per 24 hours, which continues from 9 a.m to 6 p.m., to a steady night flow at the rate of approximately 3,500 gallons per 24 hours.

In wet weather the flow varies rapidly, and has been observed to increase in the proportion of 4·5 to 1 within a period of 10 minutes, as the result of a short shower.

Subsoil Water.—From the small flow of night sewage in dry weather, it is evident that the quantity of subsoil water gaining access to the sewers at such time is not large.

On Diagram Z are given some illustrations of the sewage flow at Withnell.

Crude Sewage.—Five sets of hourly samples of crude sewage, drawn according to rate of flow, and two chance samples were examined chemically. The hourly sets consisted of two series of three and two respectively; Series A, comprising Nos. 3493, 3,500 and 3,510, represented the whole 24 hours' flow of sewage over three days (Monday to Thursday), while series B, comprising Nos. 3501A and 3511, represented the flow of 16 to 18 hours, the sewage from about 8 a.m. to 2 and 4 p.m. being omitted. The object of drawing this second series was to get samples corresponding to the hourly sets of precipitation liquor, which corresponded to the hourly sets of effluent from the polarite filters.

All the above hourly samples were drawn in the middle of July, 1904, the weather being dry. They may therefore be taken as typical of the dry weather summer sewage at Withnell.

The following results were obtained :—

Hourly Samples, Series A.	Parts per 100,000	Average.	Number of Estimations.
Ammoniacal Nitrogen	(5·01 to 5·52)	5·35	(3)
Albuminoid Nitrogen	(0·98 to 1·54)	1·23	(3)
Total Organic Nitrogen	(2·16 to 2·93)	2·67	(3)
Oxidized Nitrogen	-	0·0	(3)
Total Nitrogen	(7·17 to 8·44)	7·68	(3)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(3·66 to 6·87)	4·88	(3)
,, ,, ,, ,, *in 4 hours*	(15·91 to 27·90)	21·19	(3)
Chlorine	(9·54 to 9·90)	9·77	(3)
Solids in Suspension	(17·30 to 52·60)	33·90	(3)
Solids by Centrifuge (vols.)	(564 and 182)		(2)
Ratio of Solids in suspension to Centrifuge Solids	(1 : 10·7 and 1 : 10·6)		(2)

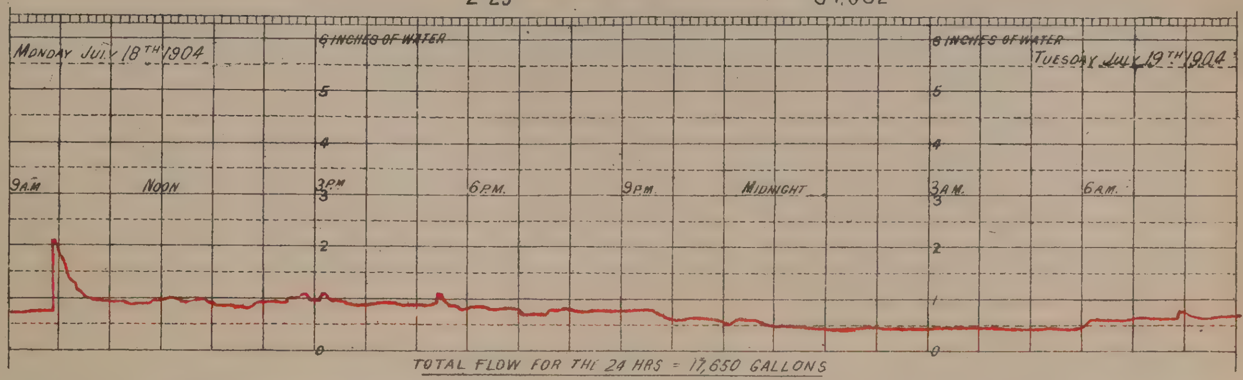
Diagram Z.

Diagrams showing flow of Sewage at Withnell as falling over a Weir 8" wide.

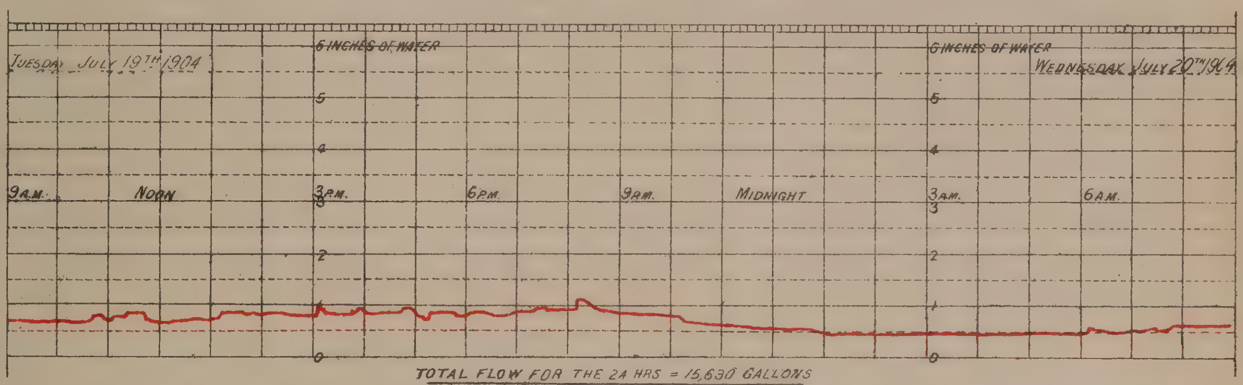
Note:- Over a Weir 8" wide

0·25 of an inch	=	a rate of	3,456	gallons	per 24 hours.
0·50 " "	=	" "	9,907	"	" " "
0·75 " "	=	" "	18,144	"	" " "
1·0 inch	=	" "	27,864	"	" " "
1·5 inches	=	" "	50,976	"	" " "
2·0 "	=	" "	78,480	"	" " "
2·25 "	=	" "	94,032	"	" " "

Dry day.
ainfall nil.



Dry day.
nfall nil.



y Day.
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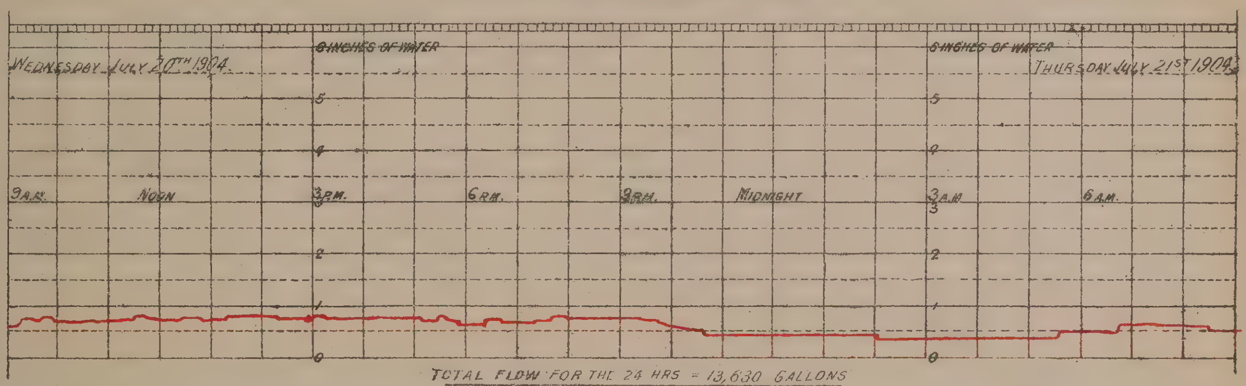
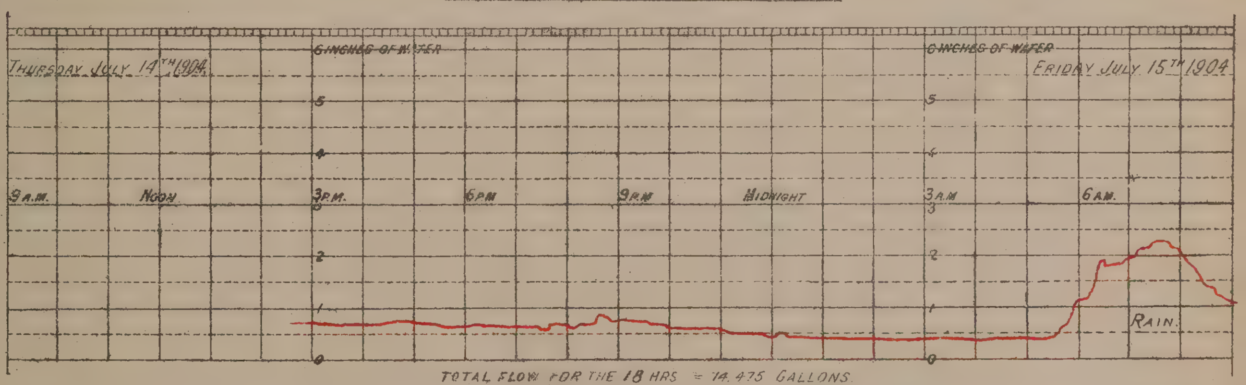
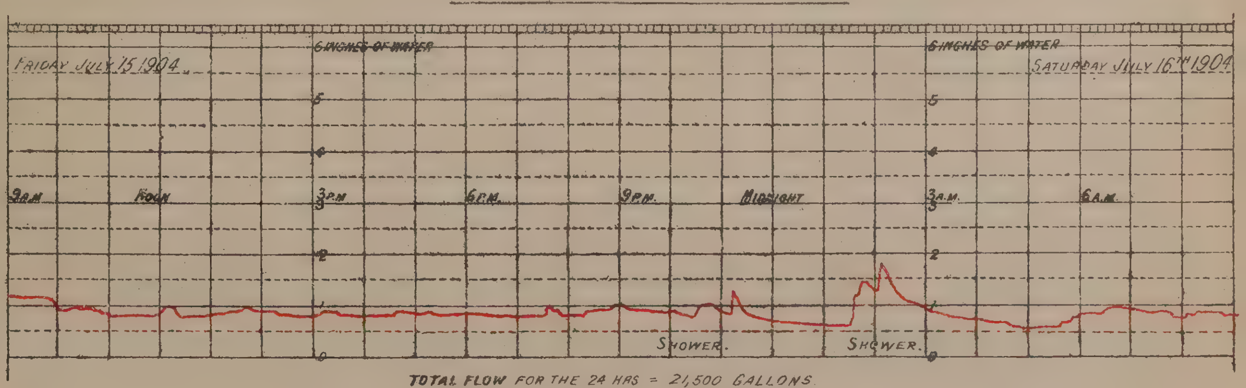


0·16 inch.
ground.



l 0·10 inch.



The dry weather summer sewage at Withnell is thus a very strong one, but it appears to vary greatly as regards suspended solids and oxidizable matter as measured by the "oxygen absorbed" test. Thus, the sample drawn on Monday–Tuesday was in both of these respects, especially the former, far stronger than that of Wednesday–Thursday. This is what might be expected, seeing that the sewage is from a small community, the great majority of whom are employed in a mill. The nitrogenous matter remained much more constant, while the chlorine figure only varied between 9·54 and 9·90. All the above samples had a sour sewage smell on the day of analysis.

The following figures were given by the two hourly sets of Series B, Nos. 3501A (16 hours) and 3511 (18 hours). Alongsideof them are placed the figures of the two chance samples examined,—No. 3505, a sample of night sewage drawn in dry weather on July 20th, 1904, at 4.30 a.m., and No. 3047, an ordinary chance sample, also taken in dry weather, on November 5th, 1902, at 1.10 p.m.

Parts per 100,000	Hourly Sets. Series B. Average.	Number of Estimations.	No. 3505. (night sewage).	No. 3047.
Ammoniacal Nitrogen - - - - -	—	—	1·63	—
Albuminoid Nitrogen - - - - -	—	—	0·29	—
Total Organic Nitrogen - - - - -	—	—	?	—
Oxidized Nitrogen - - - (0·0)	—	—	0·0	—
Total Nitrogen - - - (6·84 and 6·41)	6·63	(2)	1·89	
"Oxygen absorbed" at 27°C. *at once* (5·07 and 3·36)	4·22	(2)	0·88	3·97
,, ,, at 27°C. *in 4 hours* (18·38 and 16·06)	17·22	(2)	2·95	16·24
Chlorine - - - - - (9·70 and 9·54)	9·62	(2)	5·94	11·38
Solids in suspension - - - 21·5 and 17·6)	19·6	(2)	3·30	—
Solids by Centrifuge (vols.) - - (178 and 163)	171·0	(2)	26·0	336
Ratio of Solids in Suspension to Centrifuge Solids - - (1 : 8·3 and to 9·3)	1 : 8·8	(2)	1 : 7·9	—

The hourly sets of Series B. had, of course, the same character as those of Series A., but they were not quite so strong organically; and this remark applies with rather greater force if we compare the *average* figures of the two samples comprising Series B with those of the two corresponding samples of A, drawn on the same days, thus:—

———	Two Sets of Series A, Nos. 3493 and 3510.	Series B., Nos. 3501A and 3511.
Total Nitrogen - - - - - - - - - - - - -	7·80	6·63
"Oxygen absorbed" *at once* - - - - - - - - -	5·27	4·22
,, ,, *in 4 hours* - - - - - - - - -	21·90	17·22
Solids in Suspension - - - - - - - - - -	35·00	19·60

Notwithstanding this, however, that portion of the dry-weather sewage at Withnell, which is treated by precipitation and subsequent filtration on polarite beds, is a very strong one as regards oxidizable matter and also rather strong in nitrogen. The contact beds treat the sewage of from 8 a.m. to 3 p.m., or thereabouts, *i.e.*, a liquid which must on the average be stronger organically than the sewage of the whole 24 hours.

The ordinary chance sample, No. 3047, was also very strong, with a large quantity of flocculent sediment (about 40 parts of suspended solids, as judged by the centrifuge figure).

No. 3505, the sample of night sewage, was comparatively clear, but not weak for a night sample.

Bacteriological Notes.—Seven samples of Withnell crude sewage were examined bacteriologically. All seven samples yielded positive results with the B. Coli test and presumptive tests for B. Coli with 1/100,000 c.c. (100,000 per c.c.), except sample

3505, which was a sample of night sewage. With one exception (3501A), all the samples yielded a positive result with the B. Enteritidis sporogenes test with 1/100 c.c. (100 per c.c.) Sample 3501A contained 1000 spores of this anaerobe per c.c.

Description of the Samples.	Number of B. Coli (or Gas-forming Coli-like Microbes).	B.S. = Bile Salt Glucose Peptone Test. N.R. = Neutral Red Broth Test. In. = Indol Test. L.P.M. = Lactose Peptone Milk Test.	B. Enteritidis Sporogenes Test.	Remarks.
3047. Withnell Crude Sewage. 5/11/02.	100,000 (+ indol) (+ clot)	100,000 N.R. 100,000 In.	100 not 1,000	
3493. Withnell Crude Sewage. 19/7/04 (24 hours average).	100,000 (+ indol) (+ clot)	100,000 B.S. 100,000 N.R. 100,000 In. 100,000 L.P.M.	100 not 1,000	
3500. Withnell Crude Sewage. 20/7/04 (24 hours average).	100,000 (– indol) (+ clot)	100,000 B.S. 100,000 N.R. 100,000 In. 100,000 L.P.M.	100 not 1,000	
3501A. Withnell Crude Sewage. 20/7/04 (16 hours average).	100,000 (+ indol) (+ clot)	100,000 B.S. 100,000 N.R. 100,000 In. 100,000 L.P.M.	1,000 not 10,000	
3505. Withnell Crude Sewage. 20/7/04 (night sewage).	10,000 not 100,000 (– indol) (+ clot)	10,000 not 100,000 B.S. 10,000 not 100,000 N.R. 100,000 In. 100,000 L.P.M.	100 not 1,000	
3510. Withnell Crude Sewage 21/7/04 (24 hours average).	100,000 (– indol) (+ clot)	100,000 B.S. 100,000 N.R. 100,000 In. 100,000 L.P.M.	100 not 1,000	
3511. Withnell Crude Sewage. 21/7/04 (16 hours average).	100,000 (+ indol) (+ clot)	100,000 B.S. 100,000 N.R. 100,000 In. 100,000 L.P.M.	100 not 1,000	

DETRITUS TANK.

Immediately upon issuing from the outfall sewer, the sewage flows through a small detritus tank (6 feet by 3 feet and 2 feet 2 inches deep), which has a capacity of 244 gallons. The matter which settles here is removed once a week and put in the sludge lagoons.

THE PRECIPITATION AND POLARITE BED PROCESS.

PRECIPITATION TANKS.

Number - - - - - - -	2.
Size of each - - - - -	44 feet by 11 feet 9 inches.
Depth - - - - - -	About 5 feet.
Capacity of each - - - -	16.156 gallons.
Total capacity - - - - -	32,312 gallons.

Construction.—Brick and cement tanks with concrete bottoms. Each tank is fitted with a floating arm and sludge valve, but is otherwise perfectly simple.

Precipitant.—The precipitant used is Alumino-ferric. It is added in the form of a block placed in the sewage channel. The total quantity of precipitant used in the years 1903 and 1904 has been eleven tons, or 5·5 tons per annum. This is equivalent to about 15·7 grains per gallon on the dry-weather flow.

Working.—The tanks are used alternately, one tank being of sufficient capacity to hold the whole dry-weather flow of sewage between the hours during which it is used each day. If a storm should occur and the one tank become full, it overflows into the second tank, which is usually standing empty or nearly so.

Starting empty, a tank receives the whole flow of sewage from about 2 p.m. until 7 a.m. the next morning. It is then cut off and, after a short rest, the supernatant liquor is drawn off by means of the floating arm and delivered to the polarite beds. The tank then remains empty during the night, and is sludged the next morning, the second tank being filled in the meantime.

On Saturdays and Sundays the whole flow of sewage thro ı hout the 48 hours is allowed first to fill No. 1 tank, then to overflow into No. 2, and finally to flow direct to the land.

Sludging.—The tanks are sludged alternately on week-days, by opening the sludge valve and sweeping the liquid sludge towards it. The sludge is delivered by this means to one of the three sludge lagoons situated at the side of the tanks, where it is allowed to drain and dry naturally. The lagoons are constructed of house and furnace ashes, and drained by agricultural pipes leading to an earthenware open-joint main drain, which connects to the Whave Brook. If necessary, the drainings can be sent with the effluent to the land.

The sludge takes several months to dry by this process, and is liable to give rise to some nuisance from smell, on occasions.

Precipitation Liquor.—Hourly Samples.—Three sets of hourly samples and four chance samples were examined chemically. The hourly sets, Nos. 3502B, 3512 and 3516, were drawn on the days of Tuesday, Wednesday, and Thursday, July 19th to 21st, 1904, in dry weather, between the hours of 8 a.m. and 4 p.m. inclusive (No. 3516 up to 2 p.m.). They therefore represented the dry-weather summer day precipitation liquor of 9·9 and 7 hours respectively, as treated on the polarite beds. The following figures were obtained on analysis :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(3·74 to 5·15)	4·35	(3)
Albuminoid Nitrogen	(0·42 to 0·53)	0·47	(3)
Total Organic Nitrogen	(1·23 to 1·42)	1·32	(3)
Oxidized Nitrogen		0·0	(3)
Total Nitrogen	(5·38 to 6·46)	5·67	(3)
"Oxygen absorbed" at 27°C. (80°F.) *at once*	(0·85 to 1·22)	0·98	(3)
,, ,, ,, ,, *in 4 hours*	(6·42 to 10·34)	7·95	(3)
Solids in Suspension	(2·20*)		(1)
†Solids by Centrifuge (vols.)	(2·5 to 13·3)	8·60	(3)
Dissolved Oxygen taken up from water by No. 3516 *in 72 hours*		11·93	(1)

In appearance these samples were opalescent and almost colourless, with only very small quantities of matter in suspension. When drawn, they had a strong odour of

* A week later, a second estimation of the suspended solids was made in a portion of sample No. 3512, after it had stood for a week in a half full bottle. This gave the figure 5·9, of which 1·7 was non-volatile on ignition (as against 1·3 non-volatile in the first estimation). The inorganic portion of the solids consisted—at all events mainly—of a basic sulphate of alumina. The precipitation liquor had thus deposited more solids—mainly organic—upon standing.

† A second centrifuge estimation, made after the addition of a drop of hydrochloric acid, showed only the merest trace of suspended matter

lemonade, but this had disappeared by the following morning without, however, an unpleasant smell having up to then developed itself. They were all alkaline in reaction, but the last one only very slightly.

The first sample, No. 3502B, was stronger than the other two, especially as regards oxidizable matter as measured by the "oxygen absorbed" test, but otherwise they were fairly uniform in composition and might be regarded as distinctly strong, organically, but clear. That the liquid still contained, however, appreciable quantities of (presumably) colloidal matter is evident from what has been stated in the note on previous page, when the suspended solids in No. 3512 showed an increase of from 2·2 to 5·9 parts in a week's time; this matter was partly a basic salt of alumina, from the precipitant used, for sample No. 3516 became almost clear when slightly acidified.

Of the above three sets of hourly samples, two, Nos. 3512 and 3516, were drawn to correspond with the hourly sewages of Series B, Nos. 3501A, and 3511, and they showed, in comparison with the latter, the following reduction in figures :—

Calculated on—	Reduction.
Total Nitrogen	20 per cent.
"Oxygen absorbed" *at once*	79 ,, ,,
,, ,, *in 4 hours*	61 ,, ,,
Solids in Suspension	?
Solids by Centrifuge (vols.)	97 (?) ,,

The reduction in suspended solids and in oxidizable matter generally, as measured by the "oxygen absorbed" test, was very good, and this is further borne out by the figure 11·93 given for the absorption of dissolved oxygen *in three days* by No. 3516. The comparative smallness of this figure shows that—for an unoxidized liquid—the oxidizable matter left in was not of a very rapidly putrescible character.

Chance Samples.—The four chance samples of precipitation liquor examined, Nos. 489, 3425A, 3597 and 3658, were all drawn during wet weather, or immediately after wet. They gave the following figures :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(0·76 to 1·61)	1·23	(3)
Albuminoid Nitrogen	(0·12 to 0·42)	0·25	(3)
Total Organic Nitrogen	(1·16)	—	(1)
Oxidized Nitrogen	(0·42 ap. to 0·55 ap.)	0·50 ap.	(3)
Total Nitrogen *	(2·52 to 3·30)	2·79	(3)
"Oxygen absorbed" at 27°C. (80°F.) *at once*	(0·44 to 0·72)	0·54	(3)
,, ,, ,, ,, *in 4 hours*	(2·12 to 3·98)	2·87	(4)
Dissolved Oxygen taken up from water in 24 hours at 18°C.	(2·25† and 2·40)	—	(2)
Chlorine	(4·90)	—	(1)
Solids in Suspension	(2·40 to 5·18)	3·94	(3)
Solids by Centrifuge (vols.)	(16·2 to 46·3)	28·4	(4)
Ratio of Solids in Suspension to Centrifuge Solids	(1 : 5·0 to 1 : 10·9)	1 : 7·6	(3)

The above samples were mostly opalescent, with a slight soapy smell, and they contained a little flocculent matter in suspension. The three last samples each contained about half a part of nitrate, and this no doubt applied to No. 489 also, for the latter had no smell on the day of analysis. If the figures of analysis be compared with those given

* The figure 2·54 for the Total Nitrogen in No. 489 may just possibly have belonged to another analysis; but this is so unlikely that it is given here.

† No. 3597 took up 2·25 parts of dissolved oxygen in 24 hours and 28·0 parts in 28 days (without correction for evolved gases).

by the hourly dry-weather samples of precipitation liquor, it will be seen that the chance wet-weather samples contained only half as much nitrogen and only one-third the amount of oxidizable matter, as measured by the four hours "oxygen absorbed" test. On the other hand the figures for suspended solids, as measured by the centrifuge, were three times as great as in the hourly samples, no doubt because of the lesser time for settlement, although they were in no case high. Very considerable quantities of storm and sub-soil waters must therefore enter the sewers at Withnell in wet weather, converting the strong dry-weather precipitation liquor into a weak one. The precipitation appears to be always good, whatever the weather.

Bacteriological Notes.—Seven samples were examined bacteriologically. Some of the samples yielded remarkably good results. For example, three samples contained less than 10 spores of B. enteritidis sporogenes per c.c. Two samples contained less than 10 B. coli per c.c. Another sample contained less than 1,000 B. coli per c.c.

Description of the Sample.	Number of B. Coli (or Gas-forming Coli-like Microbes).	B.S. = Bile Salt Glucose Peptone Test. N.R. = Neutral Red Broth Test. In.—Indol Test. L.P.M. = Lactose Peptone Milk Test.	B. Enteritidis Sporogenes Test.	Remarks.
489. Withnell Precipitation Tank Liquor. 5/3/03.	—	1,000 not 10,000 B.S. 1,000 not 10,000 N.R. 10,000 not 100,000 L.P.M.	100 not 1,000	
3425 (A). Withnell Precipitation Tank Liquor. 16/3/04.	1,000 not 10,000 (– indol) (– clot)	10,000 not 100,000 N.R.	10 not 100	
3502 (B). Withnell Precipitation Tank Liquor. 20/7/04. (Average of 9 hours.)	Negative 1/10 c.c.	Negative 1/10 c.c. B.S. " " N.R. " " In. " " L.P.M.	1 not 10	
3512. Withnell Precipitation Tank Liquor. 21/7/04. (Average of 9 hours.)	Negative 1/10 c.c.	Negative 1/10 c.c. B.S. " " N.R. " " In. " " L.P.M.	1 not 10	
3516. Withnell Precipitation Tank Liquor. 21/7/04. (Average of 7 hours.)	100 not 1,000 (– indol) (– clot)	100 not 1,000 B.S. 100 not 1,000 N.R. 100 not 1,000 In. 100 not 1,000 L.P.M.	1 not 10	
3597. Withnell Precipitation Tank Liquor. 10/1/05.	At least 10,000 (+ indol) (+ clot)	At least 10,000 B.S. At least 10,000 N.R.	10 not 100	
3658. Withnell Precipitation Tank Liquor. 5/10/05.	—	10,000 not 100,000 B.S. 100,000 N.R.	10 not 100	

POLARITE FILTERS.

Number - - - - -	5.
Size of each - - - -	2 Filters, each 18 feet by 14 feet. 3 Filters, each 12 feet 3 inches by 6 feet 8 inches.
Total area - - - -	83·2 square yards.
Depth of material - - -	3 feet 3 inches.
Total cubic content - - -	90 cube yards.
Material (Top) - - - -	Sand 9 inches; polarite and sand, 15 inches.
" (Bottom) - - -	Gravel 15 inches.

Construction.—Brick and cement walls, with concrete bottoms.

Distribution.—One iron trough laid down the centre of each bed, on the surface of the sand.

Under-draining.—Twelve lines of 4 inch agricultural pipes, laid herring-bone fashion, which connect to a main drain constructed of brick on edge and tiles. On each side of the bed the ends of two tributary drains are carried up through the sand, and are thus open to the air.

Working.—The polarite filters may be divided into two sets, (A) Nos. 1, 2 and 3, the small beds which were constructed in 1894, and (B) Nos. 4 and 5, the large beds which were constructed in 1900. The three old beds on Tuesday and Friday receive the tank liquor which has come down on the previous afternoon and night, being worked ponded for the whole time, *i.e.*, for about eight hours each day. The large beds, Nos. 4 and 5, receive on Wednesdays and Thursdays the tank liquor which has come down on the previous afternoon and night, in flushes discharged once every 45 minutes. These are therefore only ponded for a few minutes at a time.

On Saturdays the top 6 inches of sand upon all the polarite filters is raked over. All these filters are washed twice or three times a year by allowing the precipitation liquor to pass down through one filter and force its way through the other, the sand on the second filter being raked in the meantime.

Polarite Filter Effluents.—As the polarite filters are worked upon two different systems, Series A (Beds 1, 2 and 3) being ponded, while Series B (Beds 4 and 5) receive precipitation liquor in flushes about every 45 minutes, it is necessary to subdivide the 9 samples, examined chemically, more than would otherwise be the case.

Series A (*Ponded Filters*).—One hourly set, No. 3517, and one chance sample, No. 3178, were examined chemically, both being dry-weather summer samples, drawn in the month of July 1904 and 1903 respectively. The hourly set, No. 3517, was made up of 7 fractions, taken in equal volumes every hour from 8.30 a.m. to 2.30 p.m., from a bed which had last been used 7 days before; while the chance sample, No. 3178, was from a bed which had been ponded for 5 hours and which had also been worked on the preceding day.

These gave the following figures on analysis :—

Parts per 100,000.	No. 3517. Hourly set.	No. 3178. Chance Sample.
Ammoniacal Nitrogen	2·71	3·33
Albuminoid Nitrogen	0·16	
Total Organic Nitrogen	0·47	—
Oxidized Nitrogen	1·78	0·63 ap.
Containing Nitrous Nitrogen	0·13	0·13
Total Nitrogen	4·96	—
"Oxygen absorbed" at 27° C. (80° F.) *at once*	0·38	0·53
" " " " " *in 4 hours*	1·37	2·30
Dissolved Oxygen taken up from water at 18°C.	more than 1·85 in 72 hours	
Incubator test (Scudder)	+	+
Incubator test (by smell)	+	—
Smell when drawn	+	+
Smell when analysed	+	+
Solids by centrifuge (vols.)	Trace.	6·0

Both of the above samples were opalescent, almost colourless, and with practically no suspended matter, and both had a clean smell when drawn (No. 3517 an odour of lemonade) and when analysed. The chance sample, however, was much less well nitrated than the other (having had obviously less nitrate to draw upon from the bed)

and it failed to withstand incubation. The hourly sample may be described as an effluent of fair quality, the chance sample not being so good. At the same time both of them were almost free from matter in suspension—a strong point in their favour.

If we compare the hourly set No. **3517** with the corresponding hourly sets of crude sewage, No. **3511**, and of precipitation liquor, No. **3516**, we get the following reduction in figures :—

Calculated on—	Compared with	
	Sewage.	Precipitation Liquor.
Albuminoid Nitrogen	—	70 per cent. reduction.
Total Nitrogen	33 per cent.	8 „ „
"Oxygen absorbed" *at once*	89 „	55 „ „
„ „ *in 4 hours*	91 „	79 „ „
Solids in suspension	nearly 100 „	Very few solids in the Precipitation liquor.

Judging from the above results, comparatively little nitrogen was actually *lost* in the passage of the precipitation liquor through this bed, or—what is more probable—any loss was compensated for by nitrate dissolved out from the material of the bed, which had been formed in it during its seven days of rest. The oxidation, as judged by the "oxygen absorbed" figures, was fair.

Polarite Filter Effluents, Series B.—Two hourly sets and four chance samples were examined chemically. The hourly samples, Nos. **3503**C. and **3513**, were drawn in dry weather in July, **1904**, and each of them represented **9** fractions of equal volume taken hourly between **8.30** a.m. and **4.30** p.m. The filters from which they were drawn had been rested for **4** and **7** days respectively. The following figures were obtained :—

	Parts per 100,000.	Average.	Number of Estimations.
Oxidized Nitrogen	(1·25 and 1·69)	1·47	(2)
Containing Nitrous Nitrogen	(0·16 and 0·03)	0·10	(2)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(0·42 and 0·27)	0·35	(2)
„ „ „ „ *in 4 hours*	(2·10 and 1·73)	1·92	(2)
Dissolved Oxygen taken up from water in 24 hours at 18°C.	(*0·49)		(1)
Incubator Test (Scudder)		2 slightly—	(2)
Incubator Test (by smell)		2 +	(2)
Smell when drawn		2 +	(2)
Smell when analysed		2 +	(2)
Solids by centrifuge (vols.)	(18·8 and 25·0)	21·9	(2)

The above samples were opalescent and almost colourless and they contained small but appreciable quantities of suspended matter; when drawn they had an odour of lemonade and when analysed a clean earthy smell. They were not so fully analysed as the hourly sample of series A, but it will be seen that they were upon the whole very similar in composition and in character, though not quite so free as the former from matter in suspension. Both of them withstood incubation and No. **3513** took up just **0·5** part of dissolved oxygen from water in **24** hours at **18**°C. So far, therefore, as the respective hourly sets are concerned, there did not appear to be any material difference in the summer dry-weather effluents obtained either by ponding or by feeding the filter in flushes, for the periods of time during which the filters are worked. Probably the effluents obtained by flushing will generally contain a little more matter in suspension, but on the other hand a bed fed by flushes should be capable of being worked for a very much longer period at one time than a bed which is ponded.

* The amount taken up in **4** days was **1·68**, *i.e.*, rather less than four times the amount taken up on the first day.

Comparing the above two hourly samples of effluent of Series B, Nos. 3503c, and 3513, with the two corresponding hourly samples of precipitation liquor, Nos. 3502B, and 3512, we find the following reduction in figures :—

Calculated on—	———
"Oxygen absorbed" *at once*	67 per cent. reduction.
" " *in 4 hours*	78 " "
Solids by centrifuge (vols.)	An increase.

This reduction in figures for "Oxygen absorbed" from permanganate is much the same as in Series A, which bears out what has been said above.

Polarite Filter Effluents (*Chance Samples*).—Of the four chance samples of polarite effluent from Series B, Nos. 490, 3179, 3598 and 3659, three were drawn in the cooler months of the year, in wet weather or just after wet; No. 3179 was a July dry-weather sample. The beds had been previously rested for 2 to 4 days, and the samples were drawn at different lengths of time (10 minutes to 6 hours) after the beds had been brought into operation for the day.

A fifth sample, No. 3426 B, drawn in March, 1904, in wet weather, was a "Works" effluent made up from filters of both Series, A and B, which had not been rested long; its figures of analysis are therefore given separately.

The following results were obtained :—

	Parts per 100,000.	Average.	Number of Estimations.	No. 3426 B.
Ammoniacal Nitrogen	(0·10 to 3·65)	1·68	(4)	0·23
Albuminoid Nitrogen	(0·06 to 0·12)	0·08	(3)	0·04
Total Organic Nitrogen	(0·17 to 0·72)	0·38	(3)	—
{ Oxidized Nitrogen	(0·53 ap. to 1·35)	0·84	(4)	0·77
{ Containing Nitrous Nitrogen		Traces	(4)	Trace
Total Nitrogen	(1·49 to 2·27)	1·79	(3)	—
"Oxygen absorbed" at 27° C. *at once*	(0·09 to 0·36)	0·26	(4)	0·09
" " " *in 4 hours*	(0·79 to 1·62)	1·29	(4)	0·85
Dissolved Oxygen taken up at 80° C. in 24 hours	(0·21 ap. to 0·41)*	0·28	(3)	0·75
Incubator test (Scudder)		2 + 2 −	(4)	Practically +
Incubator test (by smell)		3 + 1 −	(4)	+
Smell when drawn		2 + 2 −	(4)	+
Smell when analysed		4	(4)	+
Chlorine	(4·60)		(1)	3·64
Solids by Centrifuge (vols.)	(trace to 25·0)	7·0	(4)	3·6
c.c. per litre.				
Oxygen in solution	(7·6)		(1)	7·6

In general appearance and character these chance samples resembled the hourly sets, and, excepting No. 490, which contained a little, they were to all intents and purposes free from suspended matter. No. 3179, the more concentrated summer sample, was of indifferent quality and failed to withstand incubation, but the other three may be described as relatively well nitrated effluents of fair to good quality, almost free from matter in suspension, and taking up very little dissolved oxygen from water in 24 hours. When drawn, however, two or three of them had a doubtful smell, No. 3598 having a somewhat strong unpleasant odour like that of carbon disulphide, which

* 1·24 in 5 days.

persisted more or less until the following day. The oxidation, therefore, on these filters apparently does not go quite so far as it might do, so as to leave an effluent with only a clean earthy odour. While there must be considerable direct oxidation of the organic matter of the precipitation liquor in its passage through the filter, the above observations appear to indicate that in this process, more than in that of the ordinary percolating filter, a considerable portion of stored nitrate is taken up by the liquid during its passage downwards.

No. 3426 B is an interesting example of an effluent from a *dilute* sewage, with good general figures of analysis, but taking up an appreciable quantity of dissolved oxygen from water.

Bacteriological Notes.—Eleven samples were examined bacteriologically; four from Set A; six from Set B; and one a mixture from Sets A and B. There was not a constant difference bacteriologically between the A and B effluents, and on the whole the results were somewhat similar. Most of the effluents contained only about 100 to 1,000 B. coli per c.c., and no less than five of them contained no spores of B. enteritidis sporogenes even in 1 c.c.

Description of the Sample.	Number of B. Coli (or Gas-forming Coli-like Microbes).	B.S. = Bile Salt Glucose Peptone Test. N.R. = Neutral Red Broth Test. In. = Indol Test. L.P.M. = Lactose Peptone Milk Test.	B. Enteritidis Sporogenes Test.	Remarks.
3178 Withnell Polarite Effluent, Set A. 1/7/03.	—	1,000 not 10,000 N.R.	1 not 10.	
3517 Withnell Polarite Effluent, Set A. 21/7/04 (average of 7 hrs.).	1,000 not 10,000 (+ indol) (+ clot)	1,000 not 10,000 B.S. 1,000 not 10,000 N.R. 10,000 not 100,000 In. 10,000 not 100,000 L.P.M.	Negative 1 c.c.	
3518 Withnell Polarite Effluent, Set A. 21/7/04	Negative 1/10,000 c.c.	10,000 not 100,000 B.S. 1,000 not 10,000 N.R. 1,000 not 10,000 In. 10,000 not 100,000 L.P.M.	Negative 1 c.c.	
3519 Withnell Polarite Effluent, Set A. 21/7/04	10 not 100. (– indol) (+ clot)	10 not 100 B.S. 10 not 100 N.R. 100 not 1,000 In. 100 not 1,000 L.P.M.	Negative 1 c.c.	
490 Withnell Polarite Effluent, Set B. 5/3/03.	—	1,000 not 10,000 B.S. 1,000 not 10,000 N.R. 1,000 not 10,000 L.P.M.	10 not 100	
3179 Withnell Polarite Effluent, Set B. 1/7/03.	—	1,000 not 10,000 N.R.	Less than 1	
3503C Withnell Polarite Effluent, Set B. 20/7/04	10,000 not 100,000 (+ indol) (– clot)	10,000 not 100,000 B.S. 10,000 not 100,000 N.R. 10,000 not 100,000 In. 1,000 not 10,000 L.P.M.	Less than 1	
3508 Withnell Polarite Effluent, Set B. 20/7/04	100 not 1,000 (+ indol) (+ clot)	100 not 1,000 B.S. 100 not 1,000 N.R. 100 not 1,000 In. 100 not 1,000 L.P.M.	1 not 10	
3598 Withnell Polarite Effluent, Set B. 10/1/05	at least 1,000 (+ indol) (+ clot)	At least 1,000 B.S. At least 1,000 N.R.	10 not 100	
3659 Withnell Polarite Effluent, Set B. 5/10/05	—	1,000 not 10,000 B.S. 10,000 not 100,000 N.R.	1 not 10	
3426B Withnell Polarite Effluent, Sets A. & B. 16/3/04.	100 not 1,000 (– indol) (– clot)	100 not 1,000 N.R.	1 not 10	

Amount of Tank Liquor treated by the Polarite Filters.—The polarite filters receive the total flow of sewage from Monday morning to Friday morning each week, less a constant quantity each day of about 5,000 gallons, which is treated upon the contact beds. On the basis of the dry-weather flow of 15,000 gallons per 24 hours, this is equivalent to 10,000 gallons per day for four days, or an average of 5,714 gallons per day for the whole week.

In dry weather, therefore, the average daily quantity treated by the whole area of polarite filters is as follows :—

Per square yard per 24 hours - - - -	68·6 gallons.
Per cube yard per 24 hours - - - -	63·5 gallons.

It will be remembered, however, that as the polarite filters receive tank liquor for only about eight hours on each of the above-mentioned days, the actual rate of filtration while they are at work is much greater than this, being approximately :—

Per square yard per 24 hours - - - -	360 gallons.
Per cube yard per 24 hours - - . - -	333 gallons.

THE TREATMENT OF CRUDE SEWAGE UPON DOUBLE CONTACT BEDS, FOLLOWED BY LAND.

PRIMARY CONTACT BEDS.

Number - - - - -		2.
Size of each - - - -		No. 1, 32 feet by 10 feet 8 inches. No. 2, 33 feet by 10 feet 8 inches.
Area of each - - - -		No. 1, 37·9 square yards. No. 2, 39·1 square yards.
Total area - - - -		77 square yards.
Depth of material - - -		5 feet.
Total cubic content - -		128·4 cube yards.
Material - - - -		Furnace clinker graded as follows :
	Top - - -	3 inches, $\frac{1}{2}$ inch diameter.
	Middle - -	3 feet 3 inches, 1 to $1\frac{1}{2}$ inches diameter.
	Bottom - -	1 foot 6 inches, 3 inches diameter.

Construction.—These primary filters are the old precipitation tanks. They are constructed of brick and cement with concrete bottoms.

Distribution.—One main wooden trough down the centre of each bed, feeding four branch troughs on either side, all laid on the surface of the material.

Under-draining.—One main drain (brick on edge covered with tiles), fed by six branch (agricultural pipe) drains on either side, the ends of which are carried up through the clinker and are thus open to the air.

Working.—Each of the primary beds is filled once a day on five days in the week, Saturdays and Sundays being set apart for resting and digging over. They are filled with the sewage which reaches the works between 7 a.m. and about 1 p.m. The time taken in filling varies considerably, but, as a rule, it is from three to four hours. The period of contact is from $1\frac{1}{2}$ to 2 hours.

Age of Beds.—The beds were first used in May, 1900. Except for the raking and digging over which takes place every Saturday, they have never been touched since that time.

Capacity.—The original total empty tank capacity of the two primary beds was 21,653 gallons, and the original water capacity, therefore, on the assumption that the material occupied half the space of the tanks when first put in, was 10,826 gallons.

When the observations commenced in November, 1902, the surface material in the primary beds appeared to be mixed with a large quantity of humus-like matter collected from the sewage, and, although by no means coagulated into a solid mass, was soft and spongy. The beds have continued in this condition during the whole of the observations, though the sponginess has appeared to increase.

Our first estimate of capacity was made in July, 1904, upon bed No. 1 taken as typical.* It gave the total primary bed capacity as approximately 4,900 gallons, or 22·6 per cent. of the original empty tank capacity, and 45·2 per cent. of the original water capacity.

More than half the original water capacity of the two beds, therefore, was lost in the first four years' working at an average rate of 0·71 of a filling for each bed per day.

In October, 1905, a second measurement of capacity was made in the same way, and gave a total capacity of about 4,400 gallons. This is equivalent to 20·3 per cent. of the original empty tank capacity, or 40·6 per cent. of the original water capacity.

The primary contact beds at Withnell, therefore, after working at a constant rate of 0·71 of a filling for each bed per day, for a period of rather more than five years, show signs of approaching their economic limit. There is no doubt that the material will shortly have to be washed or renewed.

Primary Contact Bed Effluents.—Two "hourly" samples and three chance samples were examined chemically. As the primary beds are only filled once a day, the term "hourly" is incorrect in this instance, but it is retained for the purpose of contrasting these effluents with the corresponding "hourly" samples of secondary contact effluent, and with the hourly samples of crude sewage.

The "hourly" samples of primary contact effluent, Nos. 3,494 and 3,514, were drawn on Monday and Wednesday, July 18th and 20th, 1904, in dry weather, each sample being made up of two discharges taken in equal quantities at mid-flow, after two hours' contact. They gave the following figures :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(2·47)		(1)
Albuminoid Nitrogen	(0·75)		(1)
Total Organic Nitrogen	(1·58)		(1)
Oxidized Nitrogen	-	0·0	(2)
Total Nitrogen	(4·05)		(1)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(2·35 and 1·35)	1·85	(2)
,, ,, ,, ,, *in 4 hours*	(8·36 and 5·05)	6·71	(2)
Incubator Test by smell	-	2 –	(2)
Smell when drawn	-	2 –	(2)
Smell when analysed	-	2 –	(2)
Chlorine	(10·70 and 10·34)	10·52	(2)
Solids in Suspension	(15·6 and 5·95)	10·80	(2)
Solids by Centrifuge (Vols.)	(143·0 and 48·0)	96·0	(2)
Ratio of Solids in Suspension to Centrifuge Solids	(1 : 9·2 and 1 : 8·1)	1 : 8·7	(2)

The above two "hourly" samples of primary effluent were brown and opaque, with an average of about 11 parts of suspended solids. The first had a soapy smell when drawn and when analysed, and the second a sewage smell. Neither of them contained any oxidized nitrogen on the day of analysis and neither withstood incubation.

* The capacity of No. 2 bed was also measured ; but as it was found to leak badly, this measurement had to be discarded.

Compared with the crude sewage, drawn about the same time, these effluents show the following reduction in figures :—

Calculated on—	Hourly Samples of Sewage compared with—	
	Series A.	Series B.
"Oxygen absorbed" *at once*	62 per cent.	56 per cent. reduction
" " *in 4 hours*	68 "	61 " "
Solids in Suspension	68 "	45 " "

The above comparisons are, of course, not strictly correct, but they are sufficiently near to show that in the dry summer weather of 1904 the impurities of the crude sewage, as measured by the above tests, were reduced on the primary contact beds by about 60 per cent.—a very great reduction.

The three chance samples of primary effluent examined chemically, Nos. 3,048, 3,427 and 3,660, were drawn in the cooler months of the year—the two last in wet or immediately after wet weather. They may all be taken as representing much more dilute sewage than the "hourly" samples. No. 3,048 was drawn when the bed was nearly empty, but the others at mid-flow. The period of contact was 2 hours in each case. The following figures were obtained :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(0·92 and 0·78)		(2)
Albuminoid Nitrogen	(0·15 and 0·23)		(2)
Oxidized Nitrogen	(0·83 to 1·66)	1·99	(3)
Containing Nitrous Nitrogen	(0·08 to 1·61)*	0·67	(3)
Total Nitrogen	(2·71)		(1)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(0·55 to 2·82)	1·45	(3)
" " " " *in 4 hours*	(1·70 to 5·06)	3·36	(3)
Dissolved Oxygen taken up at 18° C. in 24 hours	(0·38 ap. and 3·00)		(2)
Incubator Test (Scudder)	1+, 2−		(3)
" " by smell	1+, 1?, 1−		(3)
Smell when drawn	2+, 1−		(3)
Smell when analysed	3+		(3)
Chlorine	(5·82 and 6·86)		(2)
Solids in Suspension	(4·30)		(1)
Solids by Centrifuge (Vols.)	(15·2 to 60·0)	38·0	(3)
Ratio of Solids in Suspension to Centrifuge Solids	(1 : 8·8)		(1)

In appearance these chance samples of primary effluent were brownish and opalescent (No. 3,427 filtered to a colourless liquid), and, excepting No. 3,048 at the time of drawing, they had all a clean smell both when drawn and when analysed. It will be seen that they contained relatively large quantities of oxidized nitrogen, almost sufficient to enable them all to withstand the incubator test. Judging from the centrifuge figures, they contained less than half the quantity of suspended solids contained in the "hourly" samples, while the average 4 hours' oxygen absorption figure was exactly half. So far as it is allowable to draw a conclusion from so few samples, it would appear that the primary contact beds at Withnell, working with one filling a day on 5 days of the week and giving 2 hours' contact, are *very nearly* capable of turning out a non-putrescent (but, of course, not a well-purified) effluent from the more dilute crude sewage of the cooler months of the year.

* This figure for Nitrous Nitrogen, 1·61, is exceptionally high.

Bacteriological Notes.—Six samples were examined bacteriologically. Most of the samples yielded positive results with the B. coli test and presumptive tests for B. coli with 1/100,000 c.c. (100,000 per c.c.). Five out of the six samples contained from 10 to 100 spores of B. enteritidis sporogenes per c.c.

Description of the Sample.	Number of B. Coli (or Gas-forming Coli-like Microbes).	B.S. = Bile Salt Glucose Peptone Test. N.R. = Neutral Red Broth Test. In. = Indol Test. L.P.M. = Lactose Peptone Milk Test.	B. Enteritidis Sporogenes Test.	Remarks.
3427. Withnell Primary Bed Effluent. 16/3/04.	1,000 not 10,000 (+indol) (+clot)	1,000 not 10,000 N.R.	10 not 100	
3048. Withnell Primary Bed Effluent. 5/11/02.	100,000 (−indol) (−clot)	100,000 N.R. 100,000 In.	100 not 1,000	
3496A. Withnell Primary Bed Effluent. 18/7/04. Bed 1.	100,000 (+indol) (+clot)	100,000 B.S. 100,000 N.R. 100,000 In. 100,000 L.P.M.	100 not 1,000	
3497X. Withnell Primary Bed Effluent. 18/7/04. Bed 2.	100,000 (−indol) (+clot)	100,000 B.S. 100,000 N.R. 100,000 In. 100,000 L.P.M.	1 not 10	
3506A. Withnell Primary Bed Effluent. 19/7/04.	100,000 (−indol) (+clot)	100,000 B.S. 100,000 N.R. 100,000 In. 100,000 L.P.M.	100 not 1,000	
3660. Withnell Primary Bed Effluent. 5/10/05.	—	10,000 not 100,000 B.S. 10,000 not 100,000 N.R.	10 not 100	

SECONDARY BED.

Number - - - - - - 1. (This is constructed in the form of a double bed, in filter tanks originally designed and used as polarite beds. The two tanks were therefore connected under the dividing wall, and in consequence the two halves of the bed now worked on the contact plan cannot be used separately.)

Size - - - - - - 29 feet by 18 feet.

Area - - - - - - 58 square yards.

Depth of Material - - - 3 feet 6 inches.

Cubic content - - - - 67·7 cube yards

Material - - - - - Furnace clinker, graded from $1\frac{1}{2}$ inches in diameter at the bottom to $\frac{1}{2}$ inch diameter at the top.

Distribution.—Two main wooden troughs down the centre of each half of the bed, delivering into five branch troughs on either side; all laid on the surface of the material.

Underdraining.—One main drain (brick on edge covered with slates) down the centre of each half of the bed, fed by 6 lines of 4-inch agricultural drain pipes, laid on either side.

Construction.—The walls are of brick and cement, and the bottoms of concrete.

Working.—The secondary bed receives the effluent from the two primary beds. It is therefore filled twice a day, except on Saturdays and Sundays. The time of contact is two hours.

Age of Bed.—The secondary bed was first used in May, 1900. Except for periodical raking, it has not been touched since.

Capacity.—We have not been able to make an accurate estimate of the water-holding capacity of the secondary contact bed, but there is no doubt that it has not suffered any serious loss of capacity during the 5½ years that it has been at work. The material at the end of the observations, in October, 1905, was still quite clean, and the bed almost held the contents of both primary beds.*

Secondary Contact Bed Effluents.—Three "hourly" and three chance samples were examined chemically. The "hourly" sets, Nos. 3495, 3504, and 3515, were drawn on July 18th and 20th, 1904, in dry weather, each set being made up of equal quantities of the two emptyings of the secondary bed for the day, drawn at mid-flow. The period of contact was 2 hours in each case. They gave the following figures :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(0·66 to 1·10)	0·89	(3)
Albuminoid Nitrogen	(0·32 to 0·51)	0·41	(3)
Total Organic Nitrogen	(1·01)	—	(1)
Oxidized Nitrogen	(0·0)	0·0	(3)
Total Nitrogen	(1·67)	—	(1)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(0·57 to 1·27)	0·89	(3)
" " " " " *in 4 hours*	(3·06 to 5·10)	3·86	(3)
Incubator Test (by smell)		3 –	(3)
Smell when drawn		3+	(3)
Smell when analysed		1+2 –	(3)
Chlorine	(10·52 to 11·06)	10·83	(3)
Solids in suspension	(3·25 to 8·60)	5·55	(3)
Solids by Centrifuge (vols.)	(45·4 to 123·0)	76·0	(3)
Ratio of Solids in Suspension to Centrifuge Solids	(1 : 12·3 to 1 : 14·3)	1 : 13·5	(3)

These secondary effluents were slightly brown and opalescent, and they contained considerable quantities of matter in suspension. They had an inoffensive smell when drawn, but two of them had a slight odour of sewage when analysed, and they all failed to withstand the incubator test. This last was not surprising, in view of their still containing a good deal of organic impurity and no nitrate.

The secondary samples, Nos. 3495 and 3515, corresponded to the primary ones, Nos. 3494 and 3514, and it may therefore be well to contrast some of their *average* figures of analysis :—

——	Primary.	Secondary.
Oxidized Nitrogen	0·0	0·0
"Oxygen absorbed" *at once*	1·85	0·92
" " *in 4 hours*	6·71	4·08
Solids in Suspension	10·80	5·90

* A rough calculation made from this datum gives the capacity of the secondary bed as being 75 per cent. of its original water capacity.

The result of the treatment of the strong dry-weather primary effluent on the secondary contact beds was thus to reduce the suspended matter and the figures for "oxygen absorbed" from permanganate by about 40 to 50 per cent., but the oxidation did not go so far as to leave any nitrate—at all events, any appreciable nitrate—in the effluent. As secondary final effluents, therefore, the above hourly dry-weather samples were unsatisfactory and required some further purification.

Although these effluents were not drawn to correspond with the hourly samples of sewage, it may be worth while to compare the two, as regards reduction in figures :—

Calculated on :—	Compared with Hourly Samples of Sewage.	
	Series A.	Series B.
Ammoniacal Nitrogen - - - - - - -	83 per cent. reduction	—
Albuminoid Nitrogen - - - - - - -	67 ,, ,,	—
"Oxygen absorbed" *at once* - - - - - -	81 ,, ,,	79 per cent. reduction
,, ,, *in 4 hours* - - - - -	80 ,, ,,	78 ,, ,,
Solids in Suspension - - - - - - -	83 ,, ,,	71 ,, ,,

Chance Samples.—The three chance samples of secondary effluent examined chemically, Nos. 3180, 3599 and 3661, were drawn in July, 1903, and in June and October, 1905, the first in dry weather and the other two in wet or immediately after wet. They were all taken at mid-flow, and the length of contact was 2 hours (1½ hours in the case of No. 3599). They gave the following results on analysis :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - - - -	(0·03 to 1·32 ap.)	0·63 ap.	(3)
Albuminoid Nitrogen - - - - - - -	- (0·10 and 0·14)	—	(2)
Total Organic Nitrogen - - - - - - -	- (0·36 and 0·32)	—	(2)
Oxidized Nitrogen - - - - - - -	- (1·0 ap. to 4·24)	2·48 ap.	(3)
Total Nitrogen - - - - - - - -	- (3·09 and 4·69)	—	(2)
"Oxygen absorbed," at 27° C. (80° F.) *at once* - -	- (0·32 to 0·56)	0·45	(3)
,, ,, ,, ,, *in 4 hours* - -	- (1·27 to 2·14)	1·71	(3)
Dissolved Oxygen taken up from water at 18°C. - -	(0·95 and 0·37)	—	(2)
Incubator test (Scudder) - - - - - - - -	3 +	—	(3)
Incubator test (by smell) - - - - - - - -	3 +	—	(3)
Smell when drawn - - - - - - - - -	- 1 (?), 2 +	—	(3)
Smell when analysed - - - - - - - - -	- 1 — 2 +	—	(3)
Chlorine - - - - - - - - - -	- (5·46 and 7·08)	—	(2)
Solids by Centrifuge - - - - - - - -	- (2·5 and 26·0)	—	(2)

These three chance samples of secondary effluent, especially the two last, were far superior in quality to the hourly samples. They were opalescent and slightly turbid in appearance, but with only small quantities of matter in suspension. Sample No. 3180 was a summer dry-weather sample, while the other two represented the effluent from the more dilute sewage of the cooler months of the year. The summer sample was an effluent of only moderate quality, but, taken altogether, they may be described broadly as well nitrated effluents which withstood incubation and which—excepting the first—had a clean smell, both when drawn and when analysed. The last sample, No. 3661, was an effluent of very good quality, taking up only 0·37 part of dissolved oxygen from water in 24 hours and 1·16 parts in five days. It had dissolved out a large

quantity of nitrate which had accumulated in the secondary bed during the rest of the preceding night. This is obvious if we compare some of its figures of analysis with those given by the primary effluent No. 3660, both of which represented the same liquid.

———	No. 3660.	No. 3661.
Total Nitrogen - - - - - - - - - - - -	2·70	4·69
Oxidized Nitrogen - - - - - - - - - - -	1·66	4·24
"Oxygen absorbed" *at once* - - - - - - - -	2·82	0·32
,, ,, *in 4 hours* - - - - - - - -	5·06	1·73
Dissolved Oxygen taken up from water *in 24 hours* - - - -	3·0	0·37

The double contact treatment at Withnell, therefore, while insufficient in the dry summer months or at other times when the sewage is specially strong, may be regarded as giving effluents of fair quality when the more dilute sewage there is being treated.

Bacteriological Notes.—Seven samples were examined bacteriologically. Most of the samples yielded positive results with the B. coli test and presumptive tests for B. coli with 1/100,000 c.c. (100,000 per c.c.). The majority of the samples contained from 10 to 100 spores of B. enteritidis sporogenes per c.c.

Description of the Sample.	Number of B. Coli (or Gas-forming Coli-like Microbes)	B.S. = Bile Salt Glucose Peptone Test. N.R. = Neutral Red Broth Test. In. = Indol Test. L.P.M. = Lactose Peptone Milk Test.	B. Enteritidis Sporogenes Test.	Remarks.
3180. Withnell Secondary Contact Bed Effluent. 1/7/03.	—	10,000 not 100,000 N.R.	10 not 100	
3498B. Withnell Secondary Contact Bed Effluent 18/7/04. First emptying.	100,000 (+indol) (+clot)	100,000 B.S. 100,000 N.R. 100,000 In. 100,000 L.P.M.	1,000 not 10,000	
3499Y. Withnell Secondary Contact Bed Effluent. 18/7/04. Second emptying.	100,000 (−indol) (−clot)	100,000 B.S. 100,000 N.R. 10,000 not 100,000 In. 100,000 L.P.M.	10 not 100	
3507B. Withnell Secondary Contact Bed Effluent. 19/7/04.	100,000 (−indol) (+clot)	100,000 B.S. 100,000 N.R. 100,000 In. 100,000 L.P.M.	100 not 1,000	
3509. Withnell Secondary Contact Bed Effluent. 20/7/04.	100,000 (+indol) (+clot)	100,000 B.S. 100,000 N.R. 100,000 In. 100,000 L.P.M.	100 not 1,000	
3520. Withnell Secondary Contact Bed Effluent. 21/7/04.	100,000 (+indol) (+clot)	100,000 B.S. 100,000 N.R. 100,000 In. 100,000 L.P.M.	10 not 100	
3361. Withnell Secondary Contact Bed Effluent 5/10/05.	—	10,000 not 100,000 B.S. 10,000 not 100,000 N.R.	1 not 10	

Amount of Sewage Treated by the Contact Bed Process.—On the basis of five fillings per week for each of the primary beds, at an estimated average total capacity of **5,000** gallons, the following quantities of grit-settled sewage have been treated by the contact bed process (primary and secondary beds together) during our observations (**1903**, **1904** and **1905**):—

Per square yard per **24** hours - - - - -	**26·4** gallons.
Per cube yard per **24** hours - - - - -	**18·2** gallons.

LAND.

On Saturdays and Sundays the liquor from the precipitation tanks is passed direct to the land, which also on a good many occasions receives the effluents from the contact and the polarite beds. This land lies on one side of the valley of the river Roddlesworth, and about half a mile to the north of the sewage works. It consists partly of sand and partly of peat and clay, and contains an area of **5½** acres. Although a few shallow land drains are laid in it, it cannot be said to be under-drained; there is, however, a main intercepting drain carried along the bottom of the slope for the collection of the effluent.

The tank liquor or filter bed effluents are carried across the higher part of the land, in a grip cut in the ground, the liquids overflowing from this and trickling slowly down, partly through the land and partly over it, to the intercepting drain at the bottom.

We have taken no samples of the land effluent, but from its appearance on the occasion of our visits it is evidently of high quality.

SUMMARY.

The sewage at Withnell is mainly a slop-water sewage, containing no trade waste, and in dry weather it is very strong organically, although it appears to vary greatly as regards quantity of suspended solids; this last circumstance is no doubt mainly due to the population being a small one, and to the fact that most of the inhabitants are employed in one industry (a large mill). Only a small proportion of subsoil water gains access to the sewers in dry weather, but in times of rain the sewage becomes diluted with large quantities of surface water.

Not more than three or four times the dry-weather flow is ever treated at the works, either on the bacterial filters or on the land, the remainder passing by an overflow into the Whave brook, which joins the larger Roddlesworth brook about half a mile away.

There is a fair grit settlement of the sewage, though we think that the grit tank might with advantage be larger than it is. The sludge from a grit tank is usually fairly thick, and therefore more easily manipulated than sludge from either the settlement or the precipitation of sewage. In some cases of precipitation it may be found advisable to allow a good deal of grit to go forward into the precipitation tank, but, speaking generally, we think it advisable to remove as much sludge by means of a grit tank as possible, preliminary to further settlement.

The precipitation effected at Withnell is excellent, more especially in dry weather, when very little ordinary suspended matter is left in the liquor; this evidently contains, however, an appreciable quantity—*i.e.*, two to three parts per **100,000**—of colloidal organic matter. The precipitation also effects a remarkable reduction in the total number of microbes. These satisfactory results are, we think, mainly due to the quiescent settlement allowed in the tanks and to the comparatively large quantity of precipitant added (**15·7** grains per gallon of alumino-ferric, calculated on the dry weather flow). The tanks are, as a rule, sludged after each filling, the sludge being run into lagoons and allowed to dry naturally, after which it is carted away to a tip. The drainings from the sludge lagoon are sometimes allowed to flow directly into the brook; although this does not appear to cause any serious nuisance, we think that the procedure is an undesirable one, and that such drainings should always be treated on bacteria beds or on land.

The polarite filters are constructed on the lines adopted by the International Company, and are 3 feet 3 inches deep. From the top downwards, they consist of 9 inches of sand, 15 inches of mixed polarite and sand, and 15 inches of graded gravel, varying from the size of a marble to pieces of 4 inches to 6 inches diameter. We think that this grading is well adapted for the treatment of a good precipitation liquor. The sand is sufficiently fine to retain particles of suspended matter on the surface, and the polarite small enough to prevent the sand from penetrating it, while the very coarse gravel at the bottom of the filter allows of free drainage and therefore of aeration. We have had no opportunity at Withnell of contrasting the purifying effect of such a filter with that of another one containing small fragments of coke, clinker, or other vesicular material in place of polarite; but, from experience gained elsewhere, we have no doubt that similar results can be obtained from a filter of the latter kind. Apart from the question of cost, polarite is a good filtering material, both as regards physical condition and durability.

Three of the filters have been in use since 1894, these being worked by the "ponding" method, while the remaining two, which are fed with precipitation liquor in flushes, were constructed in 1900. Each filter treats an average of 63·5 gallons of precipitation liquor per cube yard per 24 hours (calculated over the whole year), but of course the volume treated in the time during which a filter is actually at work is very much greater than this (approximately 333 gallons per cube yard per 24 hours). All five filters appear to be in as good condition to-day as when they were started; they seem, practically speaking, to be permanent.

Only one hourly set of effluent samples from a "ponded" filter, and two from a "flush" filter were examined chemically, but so far as the comparison of these goes, there does not appear to be any material difference in the quality of the dry weather effluents obtained for the periods of time during which the filters are actually worked. No filter treats on the average a large volume or receives precipitation liquor for more than ten hours at a time. We made no experiment at Withnell to ascertain the limit of time over which ponding could be carried with safety as regards quality of effluent, but there can be no doubt that a filter fed by flushes must be capable of being worked over a very much longer period than one which is ponded.

The hourly sets of effluent examined from both types of polarite filter were of fair quality, and (especially the sample from the ponded filter) very free from matter in suspension. The chance samples obtained by the filtration of the more dilute precipitation liquor of the cooler months of the year were relatively well nitrated effluents of fair to good quality, and almost free from suspended solids. So far as our observations go, we think that, while there must be considerable oxidation of the nitrogenous and other organic matter of the precipitation liquor when passing through the filter, purification must also depend in some degree upon the dissolving out of stored up nitrate from the filtering material. In other words, the indications are that the oxidation *during the actual passage* of precipitation liquor through filters of this kind is not so pronounced as in the ordinary type of percolating filter. Bacteriologically, many of the polarite effluents were very satisfactory, relatively speaking; no constant difference could be established between effluents from the two types of filter.

The object of laying down contact beds at Withnell, in the year 1900, was to see whether a satisfactory effluent could be obtained by this process, with a view to avoiding the expense entailed by precipitation and sludging. There is no special point to be noted with regard to the construction of the contact beds, excepting that the surface material of the primary beds is fine (½ inch diameter), and the ends of the underdrains are carried up through the clinker to the air. Each of the two primary beds receives on an average 0·71 filling of grit-settled sewage per 24 hours over the whole year (actually one filling per day upon five days of the week), the dry weather sewage being very strong organically and containing about 20 parts of suspended solids. For primary beds treating a strong sewage, they give a good reduction of impurity. After having been worked at the above rate for five and a half years, the capacity of the beds was reduced to about 40 per cent. of the original water capacity, and hence their economic "life" may be estimated at about six years. This long "life" may be ascribed to the small number of fillings per week, to the care which has been taken to keep the beds in condition by forking and raking, and also in some measure

to the fineness of the material on the surface of the beds. Some of the loss of capacity is, no doubt, due to the fact that the furnace clinker which forms the filtering medium has broken down appreciably.

The (single) secondary bed, whose capacity is double that of each of the primary ones, receives the effluent from both primary beds, but not at the same time; it has, therefore, an average of **1·4** *half-fillings* per **24** hours over the whole year (two half-fillings per day on five days of the week). The effect of this treatment on the dry weather primary effluents was to reduce the suspended matter and the **4** hours "oxygen absorbed" figure by about **40** to **50** per cent., but the oxidation did not go so far as to yield permanently nitrated effluents, nor did those effluents withstand incubation. If, therefore, they were to be judged from the standpoint of final effluents, *per se*, the dry weather secondary contact bed effluents would be unsatisfactory; they still require some further purification. These dry weather samples contained about **6** parts per **100,000** of suspended solids. We think that if the secondary beds were constructed of finer material, the effluent would be improved both in this and in other respects. The more dilute wet weather samples of secondary effluent were effluents of fair quality.

The secondary bed has not lost greatly in capacity. We have been unable to gauge it accurately, but an approximate calculation, which is probably fairly correct, gave its capacity at the end of the observations (*i.e.*, after **5½** years' working), as equal to about **75** per cent. of its original water capacity.

The contact beds, primary and secondary together, treat *on an average* **18·2** gallons of crude sewage per cube yard per **24** hours, over the whole year.

Although the total number of samples examined from Withnell was not large, there can be no doubt that the concentrated dry weather effluents from the polarite filters, treating **63·5** gallons of precipitation liquor per cube yard, were better than the secondary effluents from the contact beds, treating **18** gallons of crude sewage per cube yard. With regard to the more dilute samples, the effluents were fair in both cases, but the polarite filter effluent had the advantage of being always bright, though both kinds of effluent were very free from suspended matter. Speaking generally, our observations at the works have led us to conclude that the polarite effluent is the better in this respect also.

Comparing the two filtration processes as a whole, the polarite filters treat over three times as much *liquid* per cube yard of filtering material as the contact beds, and give better results as regards quality of effluent; but against this must be placed the cost of precipitant, precipitation tanks and sludging.

The true final effluent at Withnell is, as a rule, the land effluent. The examination of this did not come within the scope of our observations, but we have looked at samples of it on several occasions, on the spot, and it appeared to be an effluent of very high quality.

The Whave brook receives both the storm overflow sewage and some of the drainings from the sludge lagoons; it could not therefore be observed for the effect of effluent upon it. In continued dry weather the brook is fairly clean, but in wet weather the polluting effect of the storm overflow discharge is strongly marked.

There is very little smell produced by the process of sludging, but considerable smell from the sludge lagoons, especially in warm, moist weather. As a general rule, however, we have found upon our visits that the works are fairly free from nuisance in this respect.

We have received much assistance from Mr. A. Marsden, the Manager of the Sewage Works, in connection with our work at Withnell. We should also like to acknowledge our indebtedness to the late Mr. T. Beaver, Surveyor to the Withnell Urban District Council.

YORK SEWAGE WORKS.

(York Corporation).

1.	Situation of works	Naburn, 4 miles from York.
2.	Methods of treatment	(1) 3,750,000 gallons per day: Chemical precipitation in continuous flow tanks; (2) 500,000 gallons per day: Open septic tank, followed by filtration through percolating filters of coarse material.
3.	Population draining to works during observations	about 80,000 (estimated average).
4.	Water supply in gallons per head, and whence obtained	36 gallons; from River Ouse—a rather hard water.
5.	Number of water closets	about 9,000.
6.	Sewerage system	(1) Old part of town—combined. (2) New part of town—partially separate.
7.	Average dry weather flow of sewage in gallons per 24 hours	4,250,000.
8.	Gallons of sewage per head per day	about 53.
9.	Character of the sewage	A domestic sewage weak in nitrogen, but containing considerable oxidizable matter.
10.	Period of observations	December, 1902, to December, 1904.
11.	Age of percolating filters	No. 1 filter, 2 years 6 months. No. 2 filter was not started until May, 1903.
12.	Amount of storm water treated	About one and a half times the dry weather flow.
13.	Total capacity (at working depth) of tanks in gallons:—(*a*) precipitation; (*b*) septic	(*a*) 875,000; (*b*) 478,650.
14.	Total area of filters in yards super	No. 1:—400; No. 2:—873.
15.	Total cubic content of filters in yards cube	No. 1, 882·6; No. 2, 2,182.
16.	Nature of filtering medium	No. 1 filter:—½ inch to 3½ inch clinker and cinders. No. 2 filter (segmented):—clinker, gas coke, slag, and hard broken brick, ½ inch to 3½ inches diameter.
17.	Gallons of septic tank liquor treated per yard super per 24 hours	No. 1 filter, 360; No. 2 filter, 360.
18.	Gallons of septic tank liquor treated per yard cube per 24 hours	No. 1 filter, 163; No. 2 filter, 140.
19.	The final effluent is discharged into	The River Ouse.

FLOW OF SEWAGE.

The City Engineer's pumping records show that the maximum quantity of sewage which the pumps feeding the Naburn sewer are capable of lifting without serious strain is 6,500,000 gallons per day. It may be said, therefore, that rather less than twice the dry weather flow of 4,250,000 gallons per day is the most that ever reaches the works for treatment. Any excess over this is pumped direct to the river at Fulford by two 24-inch centrifugal stand-by pumps.

Most careful records of the sewage flow and rainfall have been kept by the City Engineer (Mr. Creer), and from these we have been able to obtain the following data :—

	Year ending 31st March.			Remarks.
	1903.	1904.	1905.	
1. Total quantity of sewage and storm water arriving at Fulford	1,734,895,800	2,098,780,380	1,821,311,100	
Total quantity of sewage and storm water pumped to Naburn Disposal Works	1,291,714,200	1,424,287,720	1,654,697,520	
2. Total quantity of storm-water pumped to river by centrifugals	101,950,000	160,100,000	50,400,000	
Do. by main pumps - -	341.231,600	514,392,660	116,213,580	
Total - - -	443,181,600	674,492,660	166,613,580	
Annual rainfall (inches) -	20·34	32·13	17·95	
Number of days on which ·01″ or more rain fell	185	220	157	
3. Number of days upon which the centrifugal and main storm water pumps were brought into use for pumping into river	101	136	95	
4. Greatest flow of sewage and storm water which arrived at Fulford on any one day	17,760,960*	22,249,000*	13,199,220*	* These figures are only approximate, as there are no means of ascertaining the quantities arriving at the Pumping Station, but only the quantities pumped. There have been occasions when, owing to a breakdown of machinery during a heavy shower of rain, or to the river being in high flood, the pumps have been utterly powerless to deal with the quantity arriving at the works; at such times the excess passes direct to the river by an overflow.
5. Lowest flow of sewage which arrived at Fulford on any one day.	2,730,960	3,193,560	3,119,940	
6. Daily figures of flow of sewage to Naburn for a *dry* week of each year		4,527,540 4,423,680 4,404,240 3,704,220 3,638,520 4,327,200 4,387,140	4,265,820 4,387,680 4,285,440 3,857,400 5,036,580 4,746,600 4,370,040	
		29,412,540	30,949,560	

Our own gauging of the sewage flow at Naburn was made in November, 1903. At this time, in consequence of the wet summer and autumn, the flow was found to be about 5,000,000 gallons per day, though the week during which the gaugings were made was a perfectly dry one. This must be borne in mind in looking at the results of the analysis of the average samples of sewage and tank liquors, for these were taken at the time of our gauging. They may, therefore, be looked upon as representing approximately average samples for the year 1903 and not for a normal year, being somewhat weaker than they would have been if the year had been a dry one.

Our estimates of the York sewage flow are as follows :—

Average dry weather flow in 1903–4 - - 4,250,000 gallons per 24 hours.

Highest (wet) day's flow in 1903–4 - (about) 22,000,000 gallons per 24 hours.

Owing to the fact that the sewage is pumped, the average flow at the works is of an even character. In wet weather a large quantity of subsoil water, and, when the river is high, even river water, undoubtedly finds its way into the sewers.

Crude Sewage.—Three sets of hourly samples, Nos. 629, 633 and 638, and one chance sample of weak night sewage, No. 637, were examined. These were drawn in dry weather in November, 1903, but the whole year was a phenomenally wet one. The hourly samples were on the whole very even in composition, as will be seen from the following figures :—

	Parts per 100,000.	Hourly Samples.	Number of Estimations.	Weak Night Sewage.
Ammoniacal Nitrogen - - - - - - -	(2·20 to 2·97)	2·58	(3)	0·78
Albuminoid Nitrogen - - - - - - -	(0·77 to 0·85)	0·82	(3)	0·27 approx.
Total Organic Nitrogen - - - - -	(1·07 to 1·46)	1·31	(3)	0·59
Oxidized Nitrogen - - - - - - -	(0·0)		(1)	0·0
Total Nitrogen - - - - - - - -	(3·27 to 4·43)	3·89	(3)	1·37
Oxygen absorbed at 27° C. (80° F.) *at once* - -	(1·60 to 2·86)	2·41	(3)	0·72
„ „ „ „ *in 4 hours* -	(12·06 to 14·73)	13·83	(3)	4·19
Chlorine - - - - - - - - -	(7·50 to 11·12)	9·22	(3)	4·36
Solids in Suspension - - - - - -	(18·6 to 24·0)	21·2	(3)	11·1
Solids by Centrifuge (vols.) - - - -	(161·0 to 186·0)	171·0	(3)	88·0
Ratio of Solids in Suspension to Centrifuge Solids	(1 : 7·8, 9·0 & 7·7)	1 : 8·2	(3)	1 : 7·9

It will be seen from the above figures that the sewage is weak as regards nitrogenous matter and suspended solids, but that it contains more than an average quantity of oxidizable matter, as judged by the "oxygen absorbed" figures. The sample of weak night sewage contained no oxidized nitrogen; it was not very weak for a sample drawn at 5.30 a.m.

Bacteriological Notes.—Only one sample was examined; it yielded the following results :—

Description of the Sample.	Number of B. coli (or gas-forming coli-like microbes).	B.S. = Bile salt glucose peptone test. N.R. = Neutral red broth test. In. = Indol test. L.P.M. = Lactose peptone milk test.	B. enteritidis sporogenes test.	Remarks.
629 Screened sewage 24/11/03.	100,000 (+indol) (+clot)	100,000 N.R.	1,000 not 10,000	

SCREENS AND DETRITUS TANKS.

The sewage is screened three times: once through a screen at Fulford before it is pumped and twice through ⅜-inch screens at the works.

There is no grit chamber in the precipitation process, but in the open septic tank and percolating filter process the sewage passes in the first instance through a grit chamber (10 feet 6 inches by 39 feet 6 inches and 6 feet 6 inches deep). The capacity of this chamber is about 17,000 gallons.

PRECIPITATION TANKS.

Number.—Originally 6, now 4. Size of each, 160 feet by 40 feet by 6 feet 6 inches deep.

Capacity.—The total precipitation tank capacity (4 tanks) is 1,000,000 gallons, each tank holding 250,000 gallons, but as the average number of tanks in use at any time is 3½ instead of 4, the working capacity may be taken as 875,000 gallons.

Working.—The tanks are used in parallel. Each tank runs for about 3½ days before it is cleared out, and it then requires 12 hours for cleaning.

Flow through.—In dry weather, with a flow of 4,250,000 gallons per 24 hours to the works, 3,750,000 gallons of which would flow to the precipitation tanks, the flow through each tank would be on an average once in 7·1 hours, at the rate of 4·5 inches per minute. In storm times, when the flow to the works reached its maximum of 6,500,000 gallons per 24 hours, 6,000,000 gallons of which would flow to the precipitation tanks, the flow through each tank would be once in 4 hours, at the rate of 8·0 inches per minute.

Precipitants.—The chemicals employed for the precipitation are alumino-ferric and lime.

The alumino-ferric is put into the inlet channel in the form of blocks, which dissolve at the rate of about 4 grains per gallon (5·7 parts per 100,000). The lime is added subsequently in the form of milk of lime at the rate of about 3 grains per gallon (4·3 parts per 100,000).

Cleaning.—One tank is cleaned out every day (except Sundays), by first draining off the supernatant liquid through floating arms and then pushing the residual sludge to the pumps connected with the sludge pump.

About 140 tons of this wet sludge are produced per day. Lime is added to this (4 grains per gallon) and the mixture is forced by rams into the presses, which produce from 20 to 25 tons of pressed cake per day. The press water runs back into the sewage flowing to the precipitation tanks, and, being strongly alkaline with lime, adds considerably to the 3 grains of lime per gallon used as a direct precipitant.

At one time the neighbouring farmers took an appreciable quantity of the pressed cake for manure, but now very little goes in this way, and, as the supply has always greatly exceeded the demand, the bulk of the cake still remains on the works. Formerly it was piled on an open heap, but owing to complaints in 1903 from the Archbishop (whose palace is about a mile higher up the river), the whole of the accumulated sludge has now been spread in a layer averaging about 8 feet deep and covered with 2 feet of earth and turf. There appears now to be little or no nuisance.

Precipitation Liquor.—Three sets of hourly samples, Nos. 630, 634 and 639, drawn in dry weather at the same time as the hourly sewage samples, were analysed. They gave the figures :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen	(2·31 to 3·02)	2·63	(3)
Albuminoid Nitrogen	(0·53 to 0·57)	0·54	(3)
Oxidized Nitrogen	(0·0)		
Total Organic Nitrogen	(0·95 and 1·00)	0·98	(2)
Total Nitrogen	(3·26 and 4·02)	3·64	(2)
"Oxygen absorbed" at 27° C. (80° F.) *at once*	(1·41 to 1·65)	1·49	(3)
" " " *in 4 hours*	(7·72 to 7·81)	7·76	(3)
Chlorine	(8·08 to 10·40)	8·86	(3)
Solids in suspension	(7·3 to 8·2)	7·7	(3)
Solids by centrifuge (vols.)	(29·0, 54·0 and 52·0)	45·0	(3)
Ratio of solids in suspension to centrifuge solids	(1 : 3·5, 7·4 and 7·0)	1 : 6·0	(3)

Here, again, the samples were very even in composition throughout, and it will be seen that there was a fair settlement of suspended solids.

As compared with the hourly samples of sewage, the percentage reduction in the precipitation liquor works out as follows:—

	Percentage reduction.
Total nitrogen	6
Albuminoid nitrogen	34
"Oxygen absorbed" in 4 hours	44
Suspended solids	64

The one chance sample of precipitation liquor which was examined partially (No. 706) was drawn after a good deal of rain had fallen. It was weaker in nitrogen than the average samples, but the 4 hours' permanganate figure was rather higher, although the sample was almost free from suspended matter.

Bacteriological Notes.—Four samples (630, 634, 639 and 706) were examined. The first three were hourly samples and 706 was a chance sample. The B. coli test and presumptive tests for B. coli (bile-salt glucose peptone, neutral red broth, indol and lactose peptone milk tests) yielded positive results with from 1/10,000 to 1/100,000 c.c. The B. enteritidis sporogenes test yielded results varying from 10 to 1,000 per c.c.

Description of the Sample.	Number of B. coli (or gas-forming coli-like microbes).	B.S.=Bile-salt glucose peptone test. N.R.=Neutral red broth test. In.=Indol test. L.P.M.=Lactose peptone milk test.	B. Enteritidis sporogenes test.	Remarks.
630. Precipitation liquor 24/11/03	10,000 not 100,000 (+indol) (+ clot)	10,000 not 100,000 N.R.	1,000 not 10,000	
634. Precipitation liquor 25/11/03	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R.	10 not 100	
639. Precipitation liquor 26/11/03	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R.	10 not 100	
706. Precipitation liquor 14/6/04	100,000 (+ indol) (+ clot)	100,000 In. 100,000 N.R. 100,000 B.S.	100 not 1,000	

SEPTIC TANKS.

Number.—2. Size of each: 160 feet by 40 feet by 6 feet 6 inches deep.

Working.—Used in series.

Capacity.—The total working capacity is 478,000 gallons.

Flow through.—The flow through the tanks is once in 26 hours, at the rate of 2·4 inches per minute, and it is practically constant.

Cleaning.—Previous to the construction of the second percolating filter, one tank, with a "flow through" of once in 35 hours, supplied all the septic tank liquor necessary to feed the No. 1 "York" filter and other experimental bacteria beds. This tank was started on July 5th, 1900, and ran till March, 1902, before being cleaned out. During this time (21 months) it received 105 million gallons (170,000 gallons per 24 hours).

On being cleaned out in March, 1902, it was found to be a quarter full of rather thick sludge of which there were 390 cubic yards. Several attempts were made to press this septic sludge in the same way as the precipitated sludge, but it was found to require a prohibitive quantity of lime. It was eventually dried in lagoons.

The tank was restarted in March, 1902. In April, 1903, a second tank was added, and the two were thenceforward used in series, with a "flow through" of once in 26 hours. They were not cleaned out again until March, 1905.

Septic Tank Liquor.—Three sets of hourly samples, Nos. 631, 635 and 640, were examined with the following results :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - - - -	(2·75 to 3·00)	2·86	(3)
Albuminoid Nitrogen - - - - - - -	(0·49 to 0·50)	0·49	(3)
Total Organic Nitrogen - - - - - - -	(0·74 to 0·82)	0·79	(3)
Total Nitrogen - - - - - - - -	(3·49 to 3·80)	3·64	(3)
"Oxygen absorbed" at 27° C. (80° F.) *at once* - - -	(1·53 to 1·89)	1·65	(3)
,, ,, ,, ,, *in 4 hours* - -	(5·33 to 7·26)	6·51	(3)
Chlorine - - - - - - - - -	(8·70 to 9·82)	9·26	(3)
Solids in Suspension - - - - - - - -	(4·9 to 6·0)	5·3	(3)
Solids by Centrifuge (vols.) - - - - - -	(29·0 to 40·0)	35·0	(3)
Ratio of Solids in Suspension to Centrifuge Solids -	(1 : 5·9, 7·4 and 6·7)	1 : 6·7	(3)

These hourly samples of septic tank liquor, drawn at the same time as the hourly samples of sewage and precipitation liquor, represent approximately the sewage of the preceding 24 hours. When they were drawn, the second tank would be fairly free from sludge. They were remarkably even in composition, and it will be noted that there was at the time a very good settlement of suspended solids.

Again comparing a few of the above figures with those of the crude sewage we get the following reduction :—

	Per centage. reduction.
Total nitrogen - - - - - - - -	6
Albuminoid nitrogen - - - - - - -	40
"Oxygen absorbed" in 4 hours - - - - -	53
Suspended solids - - - - - - - -	75

On the basis of these results, and bearing in mind the fact of the septic tank liquor not being *strictly* comparable with either the sewage or the precipitation liquor, the septic tank liquor showed a greater reduction of organic impurity than the precipitation liquor, and should therefore have been easier to treat on the filters.

The five chance samples of septic tank liquor examined, Nos. 3074, 500, 518, 3167A and 3395, gave the following figures :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - - - -	(2·56 and 2·03)	2·30	(2)
Albuminoid Nitrogen - - - - - - -	(0·49 and 0·35)	0·42	(2)
Total Organic Nitrogen - - - - - - -	(1·50 and 0·98)	1·24	(2)
Total Nitrogen - - - - - - - -	(3·01 to 4·06)	3·71	(3)
"Oxygen absorbed" at 2° C. (80°F.) *at once* - -	(1·37 to 2·28)	1·87	(5)
,, ,, ,, ,, *in 4 hours* - -	(5·31 to 8·46)	6·51	(5)
Chlorine - - - - - - - - -	(7·44 to 10·27)	8·87	(3)
Solids in Suspension - - - - - - -	(2·7 to 11·2)	8·2	(3)
Solids by Centrifuge (vols.) - - - - - -	(20·0 to 60·0)	32·0	(5)
Ratio of Solids in Suspension to Centrifuge Solids -	(1 : 5·4, 2·0 and 9·0)	?	(3)

It will be seen that although, *on the average*, the figures of analysis are very much the same here as for the hourly samples of septic tank liquor, the individual differences in the chance samples are more marked. This was, of course, to be expected, from the variations in rainfall, etc. But, allowing for this, the differences are not on the whole great; in other words, the filters at York are called upon to treat a septic tank liquor which is not very strong and which remains fairly uniform both in quantity and quality

throughout. Three of these samples (Nos. 3074, 3395 and 500) were taken at times when there was only one septic tank in use. Two of them contained as much as 11·2 and 10·7 parts of suspended solids, showing that the tank then required cleaning out.

Bacteriological Notes.—In all, ten samples (hourly, ordinary chance, and experimental) were examined. The B. coli test and presumptive tests for B. coli (bile-salt glucose peptone, neutral red broth, indol and lactose peptone milk tests) yielded positive results with from 1/10,000 to 1/100,000 c.c.—usually with 1/100,000 c.c. The B. enteritidis sporogenes test yielded (with one exception) positive results with from 1/100 to 1/1,000 c.c.—usually with 1/100 c.c.

Description of the Sample.	Number of B. coli (or gas-forming coli-like microbes.)	B.S.=Bile-salt glucose peptone test. N.R.=Neutral red broth test. In.=Indol test. L.P.M.=Lactose peptone milk test.	B. Enteritidis sporogenes test.	Remarks.
3074. Septic liquor - 16/12/02	10,000 not 100,000 (– indol) (– clot)	100,000 In. 100,000 N.R. 10,000 L.P.M. 100,000 B.S.	100 not 1,000	
3090a. Septic liquor - 15/1/03	100,000 (– indol) (– clot)	10,000 not 100,000 In. 100,000 N.R.	1,000 not 10,000	2,100 000 microbes per c.c. (agar at 37° C.)
518. Septic liquor - 21/4/03	—	10,000 not 100,000 N.R.	100 not 1,000	
3167a. Septic liquor - 16/6/03	—	100,000 N.R.	10 not 100	
631. Septic liquor - 24/11/03	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R.	100 not 1,000	
635. Septic liquor - 25/11/03	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 N.R.	100 not 1,000	
640. Septic liquor - 26/11/03	100,000 (+ indol) (+ clot)	100,000 N.R.	100 not 1,000	
710. Septic liquor - 28/6/04	100,000 (+ indol) (+ clot)	100,000 In. 100,000 N.R. 100 000 B.S. 100,000 L.P.M.	1,000 not 10,000	
715. Septic liquor 29/6/04	100,000 (+ indol) (+ clot)	100,000 In. 100,000 N.R. 100,000 B.S. 100,000 L.P.M.	100 not 1,000	
720. Septic liquor - 30/6/04	100,000 (– indol) (+ clot)	100,000 In. 100,000 N.R. 100,000 B.S. 100,000 L.P.M.	100 not 1,000	

PERCOLATING "YORK" FILTERS.

Number of filters.—2. Dimensions: No. 1, 67 feet 6 inches diameter, 6 feet 6 inches deep; No. 2, 100 feet diameter, 7 feet 8 inches deep. Areas: No. 1, 400 square yards; No. 2, 873 square yards. Cubic contents: No. 1, 882·6 cubic yards; No. 2, 2,182 cubic yards.

Construction.—*No.* 1.—The filter is circular. It is laid upon a cement concrete floor which has a fall of about 6 inches from the centre to the circumference. On this floor a 9-inch brick wall, built in pigeon-hole work, is carried up to a height of 8 feet 9 inches,

and the space inside is filled to a depth of 6 feet 6 inches with clinker and cinder (*i.e.*, imperfectly-burned clinker), obtained from various works in the city.

As the clinker and cinder were put in, perforated unglazed pipes, 4 inches and 6 inches in diameter, were laid radially on the surface and at heights of 2 and 4 feet from the floor, for the purpose of supplying air to the filter. In all, 24 lines of these pipes were laid.

In April, 1903, when a grit tank was being constructed at the entrance of the septic tanks, half of the No. 1 filter was opened out down to the floor. The material was found to be clean and in good condition, except the bottom 9 inches. This was largely composed of fine gritty ashes and sewage suspended matter, the former having obviously resulted from the disintegration of the clinker.

Before replacing the material, the half floor exposed was covered with tiles placed on bricks, laid radially between the grooves on the floor. The material, after having been riddled, was then put back. New clinker was only added to make up the deficiency caused by the riddling.

No. 2.—In No. 2 filter, which is also circular, the concrete floor falls from the circumference to the centre and, consequently, although the filter effluent flows, as in No. 1 filter, from all parts of the outside rim to the surrounding channel, a basin is formed underneath the filter. This basin is intended to serve as a trap for suspended matter and it can be emptied.

On the floor are built 4½-inch pigeon-hole dwarf walls, varying from 6 to 15 inches apart, and carried to a uniform height of 7 inches above the level of the floor at its circumference. On these walls expanded metal is laid to form a false floor for the filtering material, and there is therefore a clear 7 inches of air space between the material and the water lying in the basin. The surrounding 9-inch pigeon-hole wall is, in the case of No. 2 filter, carried to a height of 7 feet 6 inches above the expanded metal floor, and the space it encloses is filled right up with material.

There are four different materials in No. 2 filter, each material being in a segment of its own, quite separate from the others.

Both filters are surrounded by channels for the collection of the effluents.

Materials.—

No. 1.—Clinker and cinder from various works in the city, 1½ inches—3½ inches diameter.

No. 2.—First segment (1,492 cube yards); clinker (1½ inches—3½ inches).
Second segment (312 cube yards); broken bricks (1½ inches—3½ inches).
Third segment (189 cube yards); slag (1½ inches—3½ inches).
Fourth segment (189 cube yards); gas coke (1½ inches—3½ inches).

Age.—No. 1 filter was started on July 5th, 1900, and was two years and six months old when we began our observations. No. 2 filter was started on April 29th, 1903.

Distribution.—The septic tank liquor which feeds both filters is brought up through the centres of the filters from below the floor, and is distributed by revolving sprinklers working automatically with water heads of 4 and 13 inches, respectively.

Volumes of septic tank liquor treated by the filters:—

No. 1 *filter.*—Since it was started in 1900, various amounts of septic liquor have been delivered on to the surface of No. 1 filter, the highest flow being 724 gallons per square yard per 24 hours, and the lowest 288 gallons per square yard per 24 hours.

During our observations, however, it has received an almost constant flow of about 360 gallons per square yard, or 163 gallons per cube yard per day.

No. 2 *filter.*—This filter has received about 360 gallons of septic liquor per square yard or 140 gallons per cube yard per 24 hours, since it was started in April, 1903.

Effluents.—Excepting the experimental effluents referred to later and two ordinary ones, all the *ordinary* hourly and chance samples of effluent examined were from Filter No. 1. The hourly samples, Nos. 632, 636 and 641, gave the following figures :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - -	(0·08 to 0·11)	0·10	(3)
Albuminoid Nitrogen - - - - -	(0·07 to 0·07)	0·07	(3)
Oxidized Nitrogen - - - - - -	(1·97 to 2·47)	2·25	(3)
Total Nitrogen - - - - - - -	(2·24 to 2·58)	2·45	(3)
Total Organic Nitrogen - - - - -	(0·11 and 0·19)		(2)
"Oxygen absorbed" at 27 °C. (80° F.) *at once* -	(0·26 to 0·33)	0·28	(3)
,, ,, ,, ,, *in 4 hours*	(1·08 to 1·34)	1·17	(3)
Chlorine - - - - - - - -	(8·50 to 9·64)	8·93	(3)
Solids in suspension - - - - - -	(1·60 to 1·90)	1·80	(3)
Solids by Centrifuge (vols.) - - - -	(15·2 to 21·8)	19·0	(3)
Ratio of Solids in Suspension to Centrifuge Solids	(1 to 13·6, 10·6 & 8·0)	1 : 10·7	
Incubator Test (Scudder) - - - - - - - -		all + (practically speaking)	(3)
,, ,, (by smell) - - - - - - - -		all +	(3)
Smell of sample when analysed - - - - - - -		all +	(3)

The above three days' sets of hourly samples were so like one another in composition as to be almost identical. They were clear and bright, with a faint brown tinge and a slight earthy smell, and the small quantity of suspended solids present in them was brown in colour and finely divided. It need hardly be said that they were excellent in quality. Of the total nitrogen present, no less than 92 per cent. was in the form of nitrate (with a trace of nitrite). Further, if we compare them with the hourly samples of tank liquor, we find the following percentage purification :—

Calculated on the Albuminoid Nitrogen	- - - - -	86 per cent.
,, ,, "Oxygen absorbed" *at once*	- - - -	83 ,,
,, ,, "Oxygen absorbed" *in 4 hours*	- - -	82 ,,
,, ,, Suspended solids	- - - - - -	66 ,,

The seven ordinary chance samples of effluent from No. 1 filter, viz., Nos. 3075, 3090B, 501, 519, 3168, 3396 and 705, gave the figures :—

	Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal Nitrogen - - - - - - -	(0·06 to 0·52)	0·25	(5)
Albuminoid Nitrogen - - - - - - -	(0·07 to 0·27)	0·15	(5)
Oxidized Nitrogen - - - - - - -	(1·50 approx. to 2·83)	2·11	(7)
Total Nitrogen - - - - - - - -	(2·28 to 3·01)	2·76	(3)
Total Organic Nitrogen - - - - - - -	(0·42 to 0·57)	0·49	(3)
"Oxygen absorbed" at 27° C. (80° F.) *at once* - -	(0·32 to 0·79)	0·60	(7)
,, ,, ,, ,, *in 4 hours* -	(0·99 to 2·44)	1·82	(7)
Dissolved Oxygen taken up in 24 hours at about 18° C.	(0·07 to 0·67)	0·32	(6)
Chlorine - - - - - - - - - - -	(7·64 to 10·13)	8·74	(4)
Solids in Suspension - - - - - - -	(3·4 to 7·9)	5·0	(6)
Solids by Centrifuge (vols.) - - - - - -	(9·0 to 81·0)	57·0	(7)
Ratio of Solids in Suspension to Centrifuge Solids -	{ 1 : 9·4, 12·4, 16·0, 12·0, 17·9, 13·7 }	1 : 13·6	(6)
Incubator Test (Scudder) - - - - - - - - - -		6 +	(6)
,, ,, (by smell) - - - - - - - - - -		7 +	(7)
Smell when drawn - - - - - - - - - - -		5 +	(5)
Smell when analysed - - - - - - - - - -		7 +	(7)

These chance samples of effluent, while not of quite such a high standard as the hourly samples, are still excellent. The only exception to be taken to them is that they contain too much suspended solids (5 parts per 100,000). Had these been settled out, the figures of analysis would, no doubt, have been much the same as those given by the hourly samples.

As compared with the septic tank liquors, these chance samples of effluent show the following purification :—

	Calculated on Hourly Samples of Tank Liquor.	Calculated on Chance Samples of Tank Liquor.
Albuminoid Nitrogen - - - - - - - -	69%	
"Oxygen absorbed" *at once* - - - - - -	64 „	68%
„ „ *in 4 hours* - - - - - - -	72 „	72 „
Suspended Solids - - - - - - - - -	6 „	39 „

The two ordinary chance samples of effluent from No. **2** filter, *i.e.*, Nos. **3167**B and **3397**, were likewise of good quality ; very much the same, in fact, as those from Filter No. **1**. From the fact of the filter being quite new, however, they contained much less suspended solids (about **1·5** parts) and were therefore better in that respect.

Bacteriological notes.—Ten samples were examined from No. **1** filter and two from No. **2** filter. Many of the samples obtained from No. **1** filter were remarkably pure (bacteriologically), and the B. coli test and the presumptive tests for B. coli not uncommonly yielded negative results with $\frac{1}{1000}$ c.c. With two exceptions all the samples yielded negative results with $\frac{1}{100}$ c.c. with the B. enteritidis sporogenes test. As regards filter No. **2**, only two samples were examined.

Description of the Sample.	Number of B. coli (or gas forming coli-like microbes).	B.S.=Bile-salt glucose peptone test. N.R.=Neutral red broth test. In.=Indol test. L.P.M.=Lactose peptone milk test.	B. Enteritidis sporogenes test.	Remarks.
3075. Percolation effluent from No. I., **16/12/02**.	**100** not **1,000** (– indol) (– clot)	**10,000** not **100,000** In. **100** not **1,000** N.R. **1,000** not **10,000** L.P.M. **100** not **1,000** B.S.	**10** not **100**	
3090b. Percolation effluent from No. I., **15/1/03**	**10,000** not **100,000** (+ indol) (+ clot)	**10,000** not **100,000** In. **1,000** not **10,000** N.R.	**100** not **1,000**	**104,000** microbes per c.c. (agar at **37**°C.)
501. Percolation effluent from No. I, **18/3/03**	—	**100** not **1,000** N.R.	**10** not **100**	
519. Percolation effluent from No. I., **21/4/03**	—	Less than **100** N.R.	**100** not **1,000**	
3168. Percolation effluent from No. I., **16/6/03**	—	**10,000** not **100,000** N.R.	**10** not **100**	
632. Percolation effluent from No. I., **24/11/03**	Less than **100**	Negative **1/100** c.c. N.R.	**10** not **100**	
636. Percolation effluent from No. I., **25/11/03**	**100** not **1,000** (– indol) (– clot)	**100** not **1,000** N.R.	**10** not **100**	
691. Percolation effluent from No. I., **26/11/03**	Less than **100**	**100** not **1,000** N.R.	**10** not **100**	
3396. Percolation effluent from No. I., **19/2/04**	**100** not **1,000** (+ indol) (– clot)	**100** not **1,000** N.R.	**10** not **100**	
705. Percolation effluent from No. I., **14/6/04**	**10,000** not **100,000** (– indol) (+ clot)	**1,000** not **10,000** In. **100** not **1,000** N.R. **10,000** not **100,000** B.S.	**10** not **100**	
3167b. Percolation effluent from No. 2, **16/6/03**	—	**10,000** not **100,000** N.R.	**1** not **10**	
3397. Percolation effluent from No. 2, **19/2/04**.	—	**1,000** not **10,000** N.R.	**100** not **1,000**	

Effect of temperature upon the "York" filter.—A large number of systematic obervations, extending over three years, have been made at York upon the temperatures of the atmosphere, the sewage, the filter bed itself (No. 1) and the filter effluent. The average winter temperature of the sewage was 4·4°C. higher than that of the atmosphere, and the average temperature of the filter effluent 1·6°C. lower than that of the sewage. In the absence of very severe weather,. of which we have had little experience, the purifying action of the filter is not appreciably influenced.

On one occasion, during some cold weather in January, 1903, we drew a sample of effluent when there were rings of ice on the surface of the bed, and found the temperature of the effluent to be as low as 4·5°C. (40°F.). While this sample was not up to the standard of the best York effluents, the deterioration in quality was not marked.

Unfortunately we have had no opportunity of testing the effect of a prolonged period of very cold weather upon the filters.

EXPERIMENT WITH THE SEGMENTED FILTER.

With a view to ascertaining the comparative values of the different filtering media, four sets of average samples were taken from the segmented filter on June 27th—30th, 1904. The weather was dry throughout the actual experiment, but a slight rainfall occurred on the evening of the 26th. The temperatures were normal for the time of year, and there was not sufficient wind to affect the distribution appreciably.

Each segment was sampled separately, the liquid being taken from the centre of the segment hourly throughout the 24 hours ; the 24 samples from each of the four segments were subsequently mixed together in equal volumes, making four final samples in all. Judged by the eye, the samples did not appear to differ to any marked extent.

The three sets of hourly samples of septic tank liquor, drawn for comparison with the effluents from the 4 segments on June, 27th—29th, 1904, were therefore also taken during practically dry weather. They gave the following figures :—

	Parts per 100,000.	Average.
Total Nitrogen - - - - - - - - - - -	(3·74 to 4·10)	3·97
"Oxygen absorbed" from permanganate at 27° C. (80° F.) *at once*	(1·21 to 1·89)	1·51
,, ,, ,, ,, ,, ,, *in 4 hours*	(4·04 to 5·51)	4·81
Solids in Suspension - - - - - - - - - -	(4·15 to 4·90)	4·43
Solids by Centrifuge (vols.) - - - - - - -	(15 to 17)	15·7
Ratio of Solids in suspension to Centrifuge Solids -	{1 : 3·5, 3·5 and 3·8}	1 to 3·6
Dissolved Oxygen taken up in 19 to 24 hours at 18° C. (5·0, 9·2 and 10·2 + x)* - - - - - - - - -		8·2 approx.

The above sets of hourly samples of septic tank liquor, drawn after the two tanks in series had run for a little over a year, without cleaning, were very slightly stronger in nitrogenous matter than the first set, but weaker as regards the permanganate figures and the suspended solids. But the differences are not really great, and here again we have evidence of the even character of the York septic tank liquor.

The four sets of experimental effluents comprised twelve samples in all, viz. : From broken brick segment, Nos. 711, 716 and 721 ; from slag segment, Nos. 712, 717 and 722 ; from coke segment, Nos. 713, 718 and 723 ; from clinker segment, Nos. 714, 719 and 724.†

The three individual samples included in each set were so near to one another in chemical composition that only the *average* figures for a set need be given here. They are as follows :—

* In this last instance the oxygen of the diluting water was exhausted.

† It will be remembered that the clinker segment was much larger than the other three.

Parts per 100,000.	Effluent from :—			
	Broken Brick.	Slag.	Coke.	Clinker.
Ammoniacal Nitrogen - -	0·21	0·05	0·06	0·01
Albuminoid Nitrogen - - - -	0·15	0·12	0·10	0·10
Oxidized Nitrogen - - - -	2·48	2·32 approx.	2·47 approx.	2 90
Total Nitrogen - - - - -	2·88	2·72	2·95	3·18
Total Organic Nitrogen - - -	?	?	?	0·27
"Oxygen absorbed" at 27° C. (80° F.) *at once* - - - - -	0·63	0·63	0·49	0·38
"Oxygen absorbed" at 27° C. (80° F.) *in 4 hours* - - - -	2·23	1·48	1·27	1·46
Dissolved Oxygen taken up in 24 hours at about 18° C. - - -	0·37	0·24	0·19	0·09
Solids in Suspension - - - -	2·00	1·73	1·22	2·15
Solids by Centrifuge (vols.) - -	30·0	29·5	24·4	33·5
Ratio of Solids in Suspension to Centrifuge Solids - - - -	1 : 15·0	1 : 17·3	1 : 20·4	1 : 15·6
Incubator test (Scudder) - - -	all +	all +	all +	all + (practically)
,, (by smell) - - -	all +	all +	all +	all +
Smell when analysed - - -	all +	all +	all +	all +

Taking all these experimental effluents together, they are very good. It will be seen, however, that if we differentiate between them, the following is the order of merit :—

1. Clinker.
2. Coke.
3. Slag.
4. Broken brick.

Between Nos. 2 and 3, there is really practically no difference.

The foregoing experiment having been made between June 27th and 30th, 1904, we thought it well to test shortly afterwards—on July 19th—the comparative rates at which liquid coloured by fluorescin came through the different segments.

The various filtrates showed :—	(*a*) Faint colour ; Minutes.	(*b*) Strong colour. Minutes.
1. Clinker (smallest material)	6	12
2. Coke	5	8
3. Slag *	8	9
4. Broken brick	2	2½

Excepting, therefore, as regards the difference between the coke and the slag, the order of the rate of percolation was the same as that of the purity of the effluent. Although the different filtering materials were all broken to be of the same size, the clinker was in reality much smaller than the other three, which did not differ much from each other in this respect.

It is obvious, we think, that—assuming ample aeration in every case—that effluent should be the best which percolates most slowly through the filtering material; and assuming the main factors governing the rate of percolation to be the vesicular na'ure of the material and its size and form, we should expect the clinker to give the best effluent and the broken brick the worst. The results actually obtained go to confirm these assumptions.

With the volume of septic tank liquor treated on the filter at the time (360 gallons per square yard per 24 hours, or 140 gallons per cube yard), the differences in quality of effluent were not great ; were the volume to be increased, we should expect these differ-

* The amount of effluent coming from the slag segment was very small, owing to a strong wind on that side of the filter. The result for this section may therefore be of no value.

ences to be accentuated. It would be of distinct interest to carry this experiment further by treating a larger volume of septic tank liquor on the segmented filter.

Bacteriological notes.—From the bacteriological point of view it is not desirable to draw any final conclusions from the analysis of only a few samples. But, on the whole, it seems certain that the clinker segment yielded the best results. This agrees with the chemical results as already stated.

Description of the Sample.	Number of B. coli (or gas forming coli-like microbes).	B.S.=Bile-salt glucose peptone test. N.R.=Neutral red broth test. In.=Indol test. L.P.M.=Lactose peptone milk test.	B. Enteritidis sporogenes test.	Remarks.
711*Percolation effluent No. II. brick segment 28/6/04	1,000 not 10,000 (+ indol) (+ clot)	10,000 not 100,000 In. 1,000 not 10,000 N.R. 1,000 not 10,000 B.S. 1,000 not 10,000 L.P.M.	100 not 1,000	
716*Percolation effluent No. II. broken brick segment 29/6/04	10,000 not 100,000 (− indol) (+ clot)	1,000 not 10,000 In. 1,000 not 10,000 N.R. 10,000 not 100,000 B.S. 10,000 not 100,000 L.P.M.	100 not 1,000	
721*Percolation effluent No. II. brick segment 30/6/04	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 In. 100,000 N.R. 10,000 not 100,000 B.S. 1.000 not 10,000 L.P.M.	100 not 1,000	
712*Percolation effluent No II. slag segment 28/6/04	10,000 not 100,000 (− indol) (+ clot)	1,000 not 10,000 In. 1,000 not 10,000 N.R. 10,000 not 100,000 B.S 1,000 not 10,000 L.P.M.	100 not 1,000	
717*Percolation effluent No. II. slag segment 29/6/04	1,000 not 10,000 (− indol) (+ clot)	10,000 not 100,000 In. 1,000 not 10,000 N.R. 1,000 not 10,000 B.S. 10,000 not 100,000 L.P.M.	100 not 1,000	
722*Percolation effluent No. II. slag segment 30/6/04	10,000 not 100,000 (− indol) (+ clot)	100 not 1,000 In. 1,000 not 10,000 N.R. 10,000 not 100,000 B.S. 1,000 not 10,000 L.P.M.	100 not 1,000	
713*Percolation effluent No. II. coke segment 28/6/04	100 not 1,000 (+ indol) (+ clot)	1,000 not 10,000 In. 1,000 not 10,000 N.R. 100 not 1,000 B.S 10,000 not 100,000 L.P.M.	100 not 1,000	
718*Percolation effluent No. II. coke segment 29/6/04	10,000 not 100,000 (+ indol) (+ clot)	10,000 not 100,000 In. 10,000 not 100,000 N.R. 10,000 not 100,000 B.S. 1,000 not 10,000 L.P.M.	10 not 100	
723*Percolation effluent No. II. coke segment 30/6/04	10,000 not 100,000 (− indol) (− clot)	1,000 not 10,000 In. 1,000 not 10,000 N.R. 10,000 not 100,000 B.S. 10,000 not 100,000 L.P.M.	1,000 not 10,000	
714*Percolation effluent No. II. clinker segment 28/6/04	100 not 1,000 (− indol) (− clot)	1,000 not 10,000 In. 100 not 1,000 N.R. 100 not 1,000 B.S. 100 not 1,000 L.P.M.	10 not 100	
719*Percolation effluent No. II. clinker segment 29/6/04	1,000 not 10,000 (+ indol) (+ clot)	100 not 1.000 In. 1,000 not 10,000 N.R. 1,000 not 10,000 B.S. 1,000 not 10,000 L.P.M.	100 not 1,000	
724*Percolation effluent No. II. clinker segment 30/6 04	100 not 1,000 (+ indol) (+ clot)	100 not 1,000 In. 100 not 1,000 N.R. 100 not 1,000 B.S. 1,000 not 10,000 L.P.M.	10 not 100	

SUMMARY.

The sewage is, on the whole, a somewhat weak one, at least this was the case during the year **1903**, when the average samples were taken.

The settlement of solids by the precipitation process is fairly good, the respective figures for suspended solids in the hourly samples of sewage and precipitation liquor being **21** and **8** per **100,000**. In connection with this it should be borne in mind that, when these observations were made, only four or five tanks were available for the precipitation process, instead of the six originally designed for it. One of these was taken for use as a septic tank in **1900**, and another in **1903**.

At the time of the drawing of the hourly samples of septic tank liquor it contained only **5·3** parts of suspended solids per **100,000**, and the highest amount we found in any sample was **11·2** parts. Taken as a whole, therefore, this liquor was comparatively free from matter in suspension. On the basis of our results, the septic tank liquor showed a greater reduction in impurity, as compared with the original sewage, than the precipitation liquor, but it must, of course, not be forgotten that the flow through the precipitation tanks is three times as rapid as that through the septic tank.

We have never observed any nuisance from smell either from the septic or from the precipitation tanks, while working, and it is worthy of note that, as a general rule, there is but little scum on the York septic tank.

The septic tank sludge at York has proved so difficult to press, without the addition of a very large amount of lime, that all attempts to press it have been abandoned. It is now settled in a lagoon, where it gives rise to a slight smell. No difficulty has been found in emptying the tanks by pumping, and this process is unattended with any serious nuisance.

Nor is any serious nuisance caused by the emptying of the precipitation sludge tanks or the subsequent pressing of this sludge. In consequence, however, of the very small demand for it, a large heap of the pressed cake accumulated on the works, and from this a nuisance did arise. Hence it was ultimately found necessary to get rid of this pressed cake altogether by burying it under two feet of soil, the smell being much reduced thereby.

Both methods of preliminary treatment—septic tank and chemical precipitation—may be looked upon as having been successful on a practical scale at York, so far as the working of the tanks and the subsequent amenability of the liquors to further purification were concerned.

All the filter effluents examined, both hourly and chance samples, were of excellent quality chemically, the only exception which might be taken to them being that some of the samples—judged from the standpoint of effluent alone—contained rather too much suspended matter. Many of the samples were also remarkably good bacteriologically. The general high quality of these effluents, notwithstanding the large volumes treated on the filters (**360** gallons per square yard or **163** gallons per cube yard per **24** hours on filter No. **1**; and **360** gallons per square yard or **140** gallons per cube yard on filter No. **2**), is due, we think, to the following factors :—

1. The septic tank liquor is not a very strong one, and it contains a comparatively small quantity of suspended solids;
2. The distribution on the filters is good;
3. The construction of the filters and the size of the clinker in filter No. **1** appear to be appropriate for the treatment of the York septic tank liquor.

No doubt, too, the uniformly good character of the effluent from these filters is in some measure due to their treating a constant volume of liquid.

The results of the examination of the various hourly samples of effluent drawn from the segmented filter, No. **2**, are of distinct interest. From these results, it would appear that, in accordance with theory, the best filtering material is that which is of such size and nature as to retard the liquid longest in its passage through a filter, provided that there is ample aeration.

We are indebted to Mr. A. Creer, city engineer of York, for much assistance in our work there, while our thanks are also due to Mr. J. Graham, the manager of the sewage works.

p. 173 Sewage essentially dom. + a little slaughter ho. & 1 small brewery
175 P'tion with Cont. Flow. 1st 3 weeks 10 gr. alumino-ferric per g. Not satisf.y with stormy day sew. Then 12 weeks at 15 gr. by day & 5 gr. by night. During rest of year 10 gr. A.F + 5 gr. lime per 24 hrs, the whole of the lime being added (as milk) bet. 8 a & 5 p.m. " [illegible] AF [illegible]"

Sludge produced.

	Gallons treated	Wet sludge Cu yds.	Wet sludge Tons	Dry %	Solid Tons
Precipitation	1,843,000	99.59	75.70	3.18	2.41
Sedimentation Cont Flow	1,843,000	60.50	46.20	4.26	1.97
Open S. T	1,690,000	17.59	13.65	6.37	0.87

176 One ton of dry lime mixed with the 13.65 tons of wet sludge [illegible], works out at 1.86 % "This Digestion, calc.d in ord.y way, result is certainly incorrect". Another calc. gives 36.65 %.

177 Av. of Analyses of Tank Liquors, (40 av. samples of each)

	Settled S	P'tion (all samples)	ST liquor	Precipitation liq. AF alone	Precipitation liq. AF + Lime
Ammoniacal NH_3	4.97	4.76	5.27	4.76	4.76
albuminoid "	0.84	0.59	0.80	0.60	0.57
Total org. N	1.69	1.33	1.74	1.45	1.23
Oxidised N	0.02	0.07	0.00	0.14	Trace
Total N	6.59	5.97	7.08	6.31	5.67
Ox. abs. at 27°C at once	1.97	1.26	1.99	1.39	1.15
in 4 hrs	7.75	5.71	7.70	6.81	4.82
Sols in suspension	9.39	6.71	9.57	8.13	5.49
				18 Samples.	22 Samples.
" " Greatest	23.7	16.7	20.1	16.7	12.7
Least	3.6	2.9	3.5	2.9	3.2

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MAY PROPERLY BE ADOPTED.

Methods of Treating and Disposing of Sewage.

APPENDIX IV.

MEMORANDA ON SPECIAL INVESTIGATIONS AND EXPERIMENTS

BY

OFFICERS OF THE COMMISSION,

TOGETHER WITH REPORTS BY DR. J. A. VOELCKER & MR. T. H. MIDDLETON

ON

MANURIAL EXPERIMENTS WITH SEWAGE SLUDGES.

Presented to both Houses of Parliament by Command of His Majesty.

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CONTENTS.

PREFATORY NOTE.

Though some of the Memoranda contained in this Appendix have only been written recently, in whole or in part, nearly all the data given in them were available for the Fifth Report of the Commission. A certain amount of work of a later date is, however, included in this Appendix, with the sanction of the Commission.

It will be noticed that the Appendix is printed in type of two sizes, but it must not be inferred from this that the Memoranda in the larger type are considered to be of more importance than the others. The smaller type has been used in the Memoranda which have been set up somewhat recently, in accordance with a regulation of the Stationery Office.

Although the name of our colleague, Mr. G. B. Kershaw, hardly appears in this Appendix, we have been much indebted to him for his help and co-operation in many ways.

December, 1909.

GEORGE McGOWAN.
A. C. HOUSTON.
COLIN C. FRYE.

NOTE BY DR. McGOWAN.

The chemical methods followed in the work of this Appendix have already been fully described in the Fourth Report of the Commission, Vol. IV., Part V. (1904). It is therefore only necessary to add a few words here.

Determination of "Free" and "Albuminoid" Ammonia.—Excepting in the case of the earlier samples from Ilford, and the samples included in Accrington Experiment No. 1, up to November, 1905, this determination has been made with ammonia-free water distilled in glass, after being slightly acidified with sulphuric acid. There were therefore only a very few doubtful results arising from the use of continuous-feed copper-still water (*cf.* Appendix III. to Fifth Report of Commission, Prefatory Note).

"Oxygen Absorbed" Test.—Unless where it is otherwise stated, this test—in the case of sewage liquors and of effluents—has invariably been carried out with "strong," *i.e.*, $\frac{N}{8}$ permanganate. In the case of the Lincoln waters, the "weak" $(\frac{N}{80})$ permanganate commonly employed in water analysis was used.

Determination of Dissolved Oxygen and of Dissolved Oxygen Absorption.—This has been done by Winkler's manganese method, as modified by Rideal and Stewart.

Some of the earlier chemical laboratory work connected with the Ilford experiments was carried out by Mr. R. S. Finlow, B.Sc., now one of the Agricultural Chemists to the Indian Government, and most of the other work up to the autumn of 1905, by Mr. R. B. Floris, F.I.C., now Chief Chemical Assistant under Dr. Houston, Director of Water Examinations, Metropolitan Water Board; Mr. E. H. Richards, B.Sc., who was subsequently in charge of the experimental station at Dorking; and Mr. A. C. Carter, F.I.C. The later work of this Appendix, from the end of 1905, has been done by Mr. Carter, Mr. A. F. Girvan, B.Sc., and Mr. W. G. Winterson, B.Sc. I can only repeat here what was said in the Prefatory Note to Appendix III. of the Fifth Report, with regard to the work done by these gentlemen for the Commission, viz., that it has been carried out with great care and thoroughness, and ingenuity also when occasion called for this. Personally, I would desire to offer them my hearty thanks for the constant and willing help that they have given to me.

GEORGE McGOWAN.

NOTE BY DR. HOUSTON.

I have acknowledged in the bacteriological Reports my great indebtedness to my assistants, and I can only repeat here that without their help and co-operation the work could never have been carried out successfully.

A. C. HOUSTON.

(6225). 1,250. Wt. 26170. 2/10. Wy. & S. 3562r.

MEMORANDUM AS TO THE BEST METHOD OF EXPRESSING OR MEASURING "STRENGTH" OF SEWAGE AS AFFECTING PURIFICATION.

Revised December, 1909.

BY DR. G. McGOWAN.

Sewages vary greatly as regards the amount—and, in certain cases, the nature—of the organic substances which they contain, but up till recently we are not aware of any comparative quantitative experiments having been made with the object of testing whether, given equal aggregate amounts of organic impurity, it is easier to purify one volume of a strong sewage (*a*) or two volumes of a dilute sewage (*b*), the latter (*b*) being made up of one volume of (*a*) and one volume of water.

The recent observations made for the Commission on the experimental filters at Accrington* showed that 100 gallons per cube yard of septic tank liquor, of average or above average strength, were rather more easily purified on percolating filters of coarse material, 9 feet deep, than 200 gallons of liquor of half the strength ; *i.e.*, the percentage purification was slightly greater in the former case. In the case of contact beds filled with rather fine and graded material, and treating an average of 80 gallons per cube yard per 24 hours, the reverse was the case ; *i.e.*, it was found somewhat easier to purify the weak liquor than the strong. Without going into further detail here on this complex question, which is discussed under the "Accrington Experiments," we think it may be taken broadly that, within ordinary limits of organic concentration and of volumes treated, there is no very marked difference between the two cases ; in other words, it is the amount and nature of the organic impurity present which mainly determine in practice the ease or difficulty of purification.

It follows from this that a determination of the "strength" of a sewage, even if it be only approximate, must be of great practical value for estimating the size and, in some degree, the type of plant which is required to purify a given volume of it.

We are satisfied that "strength" of sewage, as affecting purification, can at the present time be best expressed and measured in terms of the amount of oxygen required for the complete, or practically complete, oxidation of its organic matter. At the same time it has been suggested by Dr. Adeney that this might with advantage be supplemented by a determination of the amount of oxygen which the sewage could take up from air or from water within a short period, say 48 hours, with the object of learning whether it contained more or less than the normal quantity of matter which was quickly oxidizable. The comparison of the figures for "oxygen absorbed" from permanganate, *at once* and *in 4 hours*, also gives information upon this latter point (*cf.* p. 4).

As Dr. Adeney has shown, the oxidation of sewage by oxygen dissolved in water, through the agency of bacteria, takes place in two distinct stages, the carbonaceous matter being first oxidized to carbonic acid and water, and then the ammonia converted into nitrite and (finally) nitrate. When a known volume of sewage is diluted with a large excess of well-aerated water, or when it is only slightly diluted and the mixture is kept shaken up in a stoppered bottle containing a plentiful supply of air, it gradually undergoes oxidation, as above. By measuring the amount of oxygen taken up, the degree of oxidizability or "strength" of the sewage can be arrived at. 100,000 parts by weight of sewage may,in this way, require from 30 to 250, or even more, parts by weight of oxygen for its complete—or nearly complete—oxidation.

It might be argued that, since some constituents of sewage (the more offensive constituents, speaking generally) are more quickly oxidized than others, it would be better not to consider the oxidation as a whole, but fractionally ; in other words, to express the "strength" of a sewage in terms of the oxygen required to act only upon the more readily oxidizable matter present. That the oxidation of a sewage, in presence of excess of dissolved oxygen, does proceed at a much greater rate in the earlier than in the later stages is well known, and it may be illustrated by the appended table, referring to

* Cf. This Appendix, pp. 31 and 56.

a domestic sewage (paper-filtered). In this case the following quantities, *by weight*, of oxygen were taken up from water by 100,000 parts of sewage :—*

In one day (24 hours) - - - - - - - -	16·8
In two days - - - - - - - - - -	20·5
In five days - - - - - - - - - -	38·1
In twenty-one days - - - - - - - -	70·3
In twenty-eight days - - - - - - - -	79·6
In one hundred and twenty-two days - - - -	101·1

In the first five days, therefore, more oxygen was taken up than in the following sixteen.

We think, however, that there is a practical argument which—in the present state of our knowledge—tells against the measuring of the "strength" of a sewage fractionally, *i.e.*, against laying most stress upon the *rate* of oxidation, viz., if it were only the more quickly oxidizable portions which required to be considered, say, 50 per cent. of the whole oxidizable matter, then an effluent which showed 50 per cent. purification on the original sewage (as judged either by the rate of dissolved oxygen absorption or by any other recognised test) would be good enough for practical purposes. As a matter of fact, speaking generally, no effluent *per se* can be considered reasonably good, from any standpoint, unless it shows not less than 80 per cent. purification on the original crude or screened sewage. It seems, therefore, a fair inference that, in considering the strength of a sewage, its complete (or nearly complete) oxidation should be taken as the practical basis.

Table A gives some data with regard to the amounts of oxygen required for the oxidation of various sewages, etc., in good tap water under aerobic conditions ; as will be seen by reference to p. 3, this table is only intended to be construed broadly. The dilutions used for these oxidations should be such as to allow of a distinct excess of oxygen being present up to the end of the experiment, but, on the other hand, they should not be too great ; extreme dilution lessens for a time the degree of absorption of dissolved oxygen by the sewage, no doubt because it diminishes the number of the bacteria and also the amount of pabulum in a given volume of the liquid.

To carry the oxidation of sewage in water to its extreme limit requires a long time. The reaction is of course facilitated if the temperature is not allowed to fall too low ; our own experiments have been made either at a temperature of about 18°–22° C. or at laboratory temperature. From the results of a considerable number of laboratory experiments, we thought that a period of about two months might be generally taken as sufficing for the oxidation of nearly all the oxidizable matter, excluding (to some extent, at least) cellulose and fat. Later results, however, appear to show that this may be too short a time under ordinary conditions of experiment. Though we have not made enough observations on the point to speak definitely, we are satisfied that the oxidation of cellulose and fat in diluted sewage, under the aerobic conditions of our experiments and at ordinary temperatures, is slow.† In practice, however, there are but few instances of the treatment of *crude* sewage on biological filters, and the amounts of cellulose and (probably) of fat which are present in the liquids usually treated (settled sewage, septic tank liquor, and precipitation liquor) are relatively small.

By making use of a mechanical shaker, attached to a suitable gas apparatus, Dr. Adeney ‡ recently succeeded in oxidizing strong septic tank liquor by means of atmospheric oxygen, with only slight dilution by water, while he at the same time followed the

* These "aerations" were done upon Ealing sewage (paper filtered). They were carried out in well-stoppered, but not jointed, bottles, which were kept in the incubator at about 18° C. (the incubator was noted for the last of the samples and may be taken for granted in the other cases). In the last of the six, the oxygen in the gas which collected at the top of the bottle was determined and deducted (without the deduction this figure was 106·3). It was not allowed for in the other cases, but would have been immaterial in the first three, at all events.

† One part of cellulose, by weight, requires only 1·2 parts of oxygen for its complete oxidation, while one part of fat requires nearly 6 parts of oxygen. Tri-palmitin $C_3H_5(OC_{16}H_{31}O)_3$ is taken here to represent fats generally.

‡ Fifth Report of the Royal Commission on Sewage Disposal, Appendix VI., p. 101, The Pollution of Estuaries and Tidal Waters, by Professor Letts and Dr. Adeney.

TABLE A.

Parts per 100,000 by weight.	Ammoniacal Nitrogen.	Total Organic Nitrogen.	"Oxygen Absorbed" from $\frac{N}{8}$ permanganate at 27° C. (80° F.). At once.	In 4 hours.	Dissolved Oxygen used up in long aeration * (partly at 18°–22° C., partly at atmospheric temperature).	Number of days sample was kept aerated.	Dilution. Volumes of tap water used.	Whether bottle was sealed with mercury joint.	Ratio of "Oxygen absorbed" in 4 hours to Oxygen taken up in long aeration, minus that required by theory for oxidation of the ammonia.	Deviation from mean; per cent.	Ratio of "Oxygen absorbed" in 4 hours to Oxygen taken up in long aeration, minus that required by theory for the oxidation of the ammonia and organic nitrogen, considered as ammonia.	Deviation from mean; per cent.	Ratio of "Oxygen absorbed" in 4 hours to Oxygen taken up in long aeration, minus that required by theory for the oxidation of two-thirds of the ammonia and organic nitrogen, considered as ammonia.	Deviation from mean; per cent.
Column.	1	2	3	4	5	6	7	7a	8		9		10	
Sewages.														
Ilford, No. 33[y] - - - -	5·81	2·72	3·67	12·38	130·0	56	149	—	1 : 8·4	+ 8	1 : 7·4	+ 10	1 : 8·4	+ 4
,, No. 33[y] (paper filtered)	5·57	0·78	1·12	4·05	53·1	56	99	—	1 : 6·9	— 11	1 : 6·1	— 9	1 : 8·4	+ 4
,, No. 57[y] - - - -	7·61	2·31	2·74	12·12	107·0	56	149	—	1 : 6·0	— 24	1 : 5·0	— 25	1 : 6·4	— 21
,, No. 61[y] - - - -	4·49	1·85	2·37	9·88	97·0	56	149	—	1 : 7·8	± 0	1 : 6·9	+ 3	1 : 7·9	— 2
,, No. 77[y] - - - -	6·05	1·76	3·01	10·86	121·7	68	149	Jointed	1 : 8·7	+ 12	1 : 8·0	+ 19	1 : 9·0	+ 11
,, No. 81[y] - - - -	6·08	1·45	3·17	8·45	87·6	225	149	Jointed	1 : 7·1	— 9	1 : 6·4	— 4	1 : 7·7	— 5
Exeter, No. 66[x] - - - -	4·33	1·95	1·97	9·82	98·0	56	149	—	1 : 8·0	+ 3	1 : 7·1	+ 6	1 : 8·3	± 0
,, No. 92[x] ‡ - - -	4·04	† 1·8 ap.	1·52	6·96	85·9	223	149	Jointed	1 : 9·7	+ 24	1 : 8·5	+ 27	1 : 9·8	+ 21
Ealing, May 25th, 1906 (paper filtered).	4·64	2·11	—	5·13	63·7	74	99	—	1 : 8·3	+ 6	1 : 6·5	— 3	1 : 8·5	+ 5
Dorking, No. 184 (unsettled) -	4·92	1·45	1·61	6·91	66·3	56	149	—	1 : 6·4	— 18	1 : 5·4	— 19	1 : 6·8	— 16
,, No. 185 (settled) -	6·09	2·19	2·70	9·81	105·4	56	149	—	1 : 8·0	+ 3	1 : 6 9	+ 3	1 : 8·2	+ 1
						Average of eleven		- -	1 : 7·8	11	1 : 6·7	12	1 : 8·1	9
Septic Tank Liquors.														
Ilford, No. 34[y] - - - -	6·96	1·05	2·81	8·18	87·3	56	149	—	1 : 6·8	— 8	1 : 6·3	— 3	1 : 7·7	— 5
,, No. 34[y] (paper filtered)	6·84	0·39 (?)	1·74	4·49	51·0	56	99	—	1 : 4·5	— 39	1 : 4·1	— 37	1 : 6·5	— 20
,, No. 58[y] - - - -	7·77	1·70	2·20	8·48	102·0	56	149	—	1 : 7·9	+ 7	1 : 7·0	+ 8	1 : 8·7	+ 7
,, No. 62[y] - - - -	4·28	1·30	1·80	6·84	78·0	56	149	—	1 : 8·6	+ 16	1 : 7·8	+ 20	1 : 9·0	+ 11
Exeter, No. 91[x] ‡ - - -	5·21	1·08	1·34	4·57	72·8	223	149	Jointed	1 : 10·9	+ 46	1 : 9·7	+ 49	1 : 11·8	+ 46
Accrington, No. 112 - -	6·32 ap.	‖ 1·5 ap.	3·18	10·19	93·0	56	149	—	1 : 6·3	— 15	1 : 5·7	— 12	1 : 6·8	— 16
Dorking, No. 187 - - - -	5·89	1·94	2·60	8·84	87·7	56	149	—	1 : 8·1	+ 9	1 : 7·0	+ 8	1 : 8·3	+ 2
Hampton, No. 2 (May 14th, 1906).	9·53	2·16	5·55	14·72	124·8 ¶	67	149 149 199	— Jointed Jointed	1 : 5·6	— 24	1 : 4·9	— 23	1 : 6·1	— 25
Rochdale, No. 3,687 § - -	5·13	1·91	8·11	13·85	82·4	205	—	Jointed	1 : 8·0	+ 8	1 : 6·3	— 3	1 : 8·3	+ 2
						Average of nine		- -	1 : 7·4	19	1 : 6·5	18	1 : 8·1	15
Precipitation Liquors.														
Kingston, No. C (February 2nd, 1906).	2·73	1·44	0·89	4·43	36·6	56	49	—	1 : 5·5	— 25	1 : 4·0	— 34	1 : 5·4	— 29
,, No. 2 (March 14th, 1906).	2·82	1·27	0·78	5·08	43·0	57	99	—	1 : 6·0	— 18	1 : 4·8	— 21	1 : 6·0	— 21
,, No. 3,662 - -	4·94	1·67	1·10	6·51	78·0	56	99	—	1 : 8·6	+ 18	1 : 7·4	+ 21	1 : 8·9	+ 17
,, No. Y (May 29th, 1906).	3·25	0·98	0·64	4·58	57·8	251	99	Jointed	1 : 9·4	+ 29	1 : 8·5	+ 39	1 : 9·9	+ 30
Chorley, No. 3,681 - -	3·32	0·78	0·40	3·92	42·6	56	99	—	1 : 7·1	— 3	1 : 6·2	+ 2	1 : 7·7	+ 1
Dorking, No. 186 - - -	6·38	1·31	1·28	5·84	69·3	56	149	—	1 : 6·9	— 5	1 : 5·9	— 3	1 : 7·9	+ 4
						Average of six		- -	1 : 6·8	16	1 : 5·7	20	1 : 7·2	17

* The figures in this column are not corrected for the small quantity of oxygen in the gas evolved during the aeration; this correction is usually, however, not a very large one, as will be seen by referring to Note ¶, and to Addendum, p. 9.
† This figure 1·8 is inferred, as double the albuminoid nitrogen, 0·9.
‡ It is just possible that the bottles containing the dilutions of Nos. 92[x] and 91[x] may have been mis-labelled; this is, however, so unlikely that they may be accepted as correct.
§ In the case of this sample the ratio of "oxygen absorbed" *at once* to that *in 4 hours* was quite abnormal, no doubt because of the trade refuse present. A fairly average ratio for a septic tank liquor is about 1 : 3·5. Applying this here, we get a *normal 4 hours'* "oxygen absorption" of 8·04, which figure has therefore been taken instead of 13·85 for the above calculation.
‖ This figure 1·5 is inferred; it will be nearly right.
¶ Three estimations were made here, the total oxygen taken up being (*a*) 121·7, (*b*) 123·2, and (*c*) 129·4 parts, respectively (mean = 124·8): correcting the two last for the small quantities of gas evolved, the figures become (*b*) 120·0 and (*c*) 126·9.

course of the reaction by determining at different intervals of time the quantity of oxygen required by a known volume of the liquor. In this way he reached the nitrification stage of the process in twelve days' time. The method is thus a great advance, as regards time required, upon the dilution method.

Although Dr. Adeney has not, so far, been able to make many oxidations of sewages by this process, there can be no reasonable doubt of its accuracy, and we think it is safe to say that it furnishes at present the quickest available means for arriving directly at the "strength" of a sewage or sewage liquor. Apart from the great saving of time, as compared with the old dilution method, it avoids the drawbacks inherent in what may possibly be too great dilution ; on the other hand, it is probably not so easy to carry out in practice.

We have long intended to make some quantitative experiments for the Commission upon the amounts of atmospheric oxygen used up by different sewage liquors in their passage through a small laboratory biological filter, kept under as constant conditions as possible, and we hope eventually to do this. Mr. Scott Moncrieff, already working upon these lines, constructed some years ago a portable experimental filter for the use of sewage works. It ought not, *prima facie*, to be impossible to keep such a filter in a condition in which it would oxidize (or better, purify) in a given time a given quantity of some standard solution, containing carbonaceous and nitrogenous matters in approximately the same proportions as these are present in sewage. The actual oxidation of the sewage under investigation would be on the lines of that effected by an ordinary biological filter, with some loss of nitrogen, and the quantity of oxygen used up in the process would be determined. Dr. Adeney failed to obtain the *complete* oxidation of sewage upon such a filter, *i.e.*, there was always some loss of nitrogen in the process.

100,000 parts by weight of an average sewage will take up about 100 parts by weight of dissolved oxygen in two months or more, an average septic tank liquor about 80 parts, and an average precipitation liquor about 60 parts. Those "average" estimates are, however, only to be taken as rough approximations.

Although the 4 hours' "oxygen absorbed" test cannot be taken as measuring accurately the carbonaceous "strength" of a sewage,* our experience leads us to consider it (using a large excess of strong acid permanganate) a good rough guide for arriving at the degree of oxidizability of domestic sewages and tank liquors, apart from the cellulose and fat which these contain, and also apart from the ammonia and organic nitrogen. The acid permanganate solution which is used in the above test has no action upon ammonia or cellulose and not much action upon fat ; it therefore leaves out of account entirely the ammoniacal portion of a sewage. From a few quantitative experiments which we have made on the point, acid permanganate probably decomposes to some extent the organic nitrogen compounds present, without, however, oxidising any of the nitrogen to nitrite or nitrate. Some more work is required on the subject, but it may be safely taken that organic nitrogen, like ammonia, is not oxidised in the above test.

1 part (*i.e.*, molecule) of ammonia requires 4 parts of oxygen for its complete oxidation to nitric acid and water ; as the ammonia in a sewage or tank liquor can be quickly determined, the amount of oxygen required by theory for its complete oxidation is at once known. The same thing applies to the nitrogen of organic nitrogen compounds, considered as ammonia, though its determination is somewhat more troublesome than that of the free and saline ammonia. Further, if we assume that nearly all the carbonaceous matter (excepting cellulose and fat), together with the organic nitrogenous matter and ammonia, would be oxidised in two months or a longer period by excess of dissolved oxygen in tap water, then the excess of oxygen, over that required by the ammonia and organic nitrogen, would have been taken up by the carbonaceous matter of the sewage. That there is apparently a fairly approximate, though by no means exact, relation between the "oxygen absorbed" from strong acid permanganate in 4 hours and the dissolved oxygen taken up from tap water by the carbonaceous matter of a sewage—apart from the ammonia and organic nitrogen considered as ammonia—is seen from Table A.

This table hardly requires explanation. Column 1 gives the ammoniacal nitrogen ; column 2 the organic nitrogen ; columns 3 and 4 the "oxygen absorbed" from strong acid permanganate *at once* and *in 4 hours ;* column 5 the dissolved oxygen taken up during the long aeration ; and columns 6 and 7 the number of days over which

* Cf. Letts and Adeney, *loc. cit.*, pp. 44–45.

the aeration extended and the degree of dilution of the sewage, etc., with tap water. Column 8 gives the ratio of the "oxygen absorbed" in 4 hours to the dissolved oxygen taken up during the long aeration, minus the oxygen required by theory to oxidize the ammonia to nitrate; column 9 the ratio of "oxygen absorbed" in 4 hours to the dissolved oxygen taken up during the long aeration, minus that required by theory for the oxidation of the ammonia plus the organic nitrogen, considered as ammonia; while column 10 is the same as column 9, excepting that here the oxidation of only two-thirds of the ammonia and organic nitrogen is allowed for. The reason for adding this last column is that, in the practical biological filtration of sewage liquors, there is always a large loss of nitrogen in the gaseous state (*i.e.*, unoxidized nitrogen), which we think may be taken, roughly, at one-third of the whole.* The percentage deviations from the mean figures are also given for columns 8, 9, and 10.

Summarizing the averages of the above ratios, we get, provisionally:—

Column in Table A.	8.	10.	9.
For sewage - - - - -	1 : 7·8	1 : 8·1	1 : 6·7
For septic tank liquor - - -	1 : 7·4	1 : 8·1	1 : 6·6
For precipitation liquor - - -	1 : 7·3	1 : 7·6	1 : 6·1

The respective average ratios in columns 8 and 10 are necessarily very much alike, while those in column 9 are of course smaller.

By applying the results given in Table A, it would appear that the relative "strength" of a sewage liquor can be arrived at rapidly, with a fair degree of accuracy, by estimating the ammoniacal and organic † nitrogen and the "oxygen absorbed" from strong acid permanganate *at once* and *in 4 hours* at 27° C. (80° F.), and afterwards making use of one of the following alternative formulæ:—

‡ (1) Column 9.	For *Sewages.*	(Ammon. + Organic N.) × 4·5 § + (Ox. abs. in 4 hrs. × 6·5).
	For *Septic Tank Liquors.*	,, ,, ,, + (,, ,, × 6·5).
	For *Precipitation Liquors.*	,, ,, ,, + (,, ,, × 6·0).
(2) Column 10.	For *Sewages.*	(Ammon. + Organic N.) × 3·0 ‖ + (Ox. abs. in 4 hrs. × 8·0).
	For *Septic Tank Liquors.*	,, ,, ,, + (,, ,, × 8·0).
	For *Precipitation Liquors.*	,, ,, ,, + (,, ,, × 7·5).
(3) Column 8.	For *Sewages.*	(Ammon. N. × 4·5) + (Ox. abs. in 4 hrs. × 8·0).
	For *Septic Liquors.*	,, ,, + (,, ,, × 7·5).
	For *Precipitation Liquors.*	,, ,, + (,, ,, × 7·5).

The variations in the individual ratios given by the same kind of sewage liquor in Table A are too great to allow of this method of arriving at their "strengths" being more than approximate. Probably the variations would have been less marked if all the long aerations had been carried out in mercury-jointed bottles, and if the small quantities of gases evolved had been allowed for.

A sewage or sewage liquor might at times contain a large proportion of some readily oxidisable substance or substances from trade wastes, which would raise the figure for "oxygen absorbed" in four hours to an undue extent—an extent out of all proportion to the increase in the long aeration figures. But in such a case the "oxygen absorbed" *at once* (or *in 3 minutes*) would also be markedly raised. As a rule the "oxygen absorbed" *at once* from "strong" $\left(i.e., \frac{N}{8}\right)$ permanganate is, in sewage and precipitation liquor, something like one-fourth of that absorbed in 4 hours (1 : 4·0), though there is no absolutely strict ratio; in septic tank liquor the average ratio appears to be rather less than this, about 1 : 3·5. Hence, any abnormality like that indicated above could be readily allowed for, by deducting the abnormal excess of the figure for oxygen absorbed *at once* from the *four hours* figure, before bringing the latter into the calculation. The

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* Cf. Fifth Report of the Commission, p. 150.

† If only the ammoniacal and albuminoid nitrogen are estimated, the organic nitrogen may be taken as being approximately twice the albuminoid.

‡ These No. 1 formulæ are the ones which have up to now been used for calculating the "strengths" of sewages, septic tank liquors, and precipitation liquors, both in the Fifth Report of the Commission and in the Appendices to that Report which deal with the subject.

§ The figure 4·5 is got from the molecular proportions:—

$$\frac{O_2 \times 4}{N_2} = \frac{128}{28} = 4{\cdot}57$$

‖ The multiple 3 represents the proportion of oxygen required for the oxidation of two-thirds of the total nitrogen, leaving out of account the nitrogen which may be lost in the biological filtration (*cf.* above)

sample of septic tank liquor from Rochdale, No. 3687, which is given in Table A, is an instance of this. On the other hand, the ratio may rise as high as 1 : 6, *e.g.*, in the case of a sewage containing much brewery refuse. Such a sewage would therefore, in theory as well as in practice, be difficult of oxidation.

As has been already said, the foregoing method of arriving at "strength" of sewage has no claim to anything like absolute accuracy. It receives practical support, however, from the results of observations which have been made for the Commission upon the quantities of different sewages and tank liquors treated per cube yard of filtering material, by different processes, at a large number of different works. We therefore bring it forward here as offering a basis for arriving quickly at the approximate relative strength of a sewage or tank liquor, and as an aid to estimating *within reasonable limits* the area of filtering material required for its efficient purification. Of course, average hourly samples of these liquors, drawn according to rate of flow over a sufficient period of time in dry weather, must be taken for analysis. In the light of further experiment and experience, the simple formulæ given on p. 4 may probably have to undergo some modification.

Although we think that the foregoing formulæ No. 1 may be used with advantage for purposes of practical calculation, it is obvious that they do not take account of all the factors in the case. The question of cellulose and fat in sewage has already been touched upon. Reference has also been made to the fact that, although it requires in theory 4 molecules of oxygen to completely oxidize 1 molecule of ammonia, in the actual biological filtration of sewage liquors a considerable portion of that ammonia—say, 30 to 40 per cent.—is always evolved as nitrogen, *i.e.*, some of the nitrogen probably never reaches the nitric acid stage of oxidation. From the filtration experiments made for the Commission upon distillery refuse,* it would appear that the more carbonaceous matter there is in the liquor, relatively to the combined nitrogen present, the greater is the percentage loss of nitrogen as such.

Tables B. and C. give the calculated "strengths" (by No. 1 formulæ) of a number of sewages (crude and settled), septic tank liquors and precipitation liquors, based upon the analyses of the hourly samples of those which were examined for the Commission, the actual figures of analysis being given in the various reports which have already been presented.†

In Table B., which deals with crude sewage, besides the figure for calculated "strength," those for "oxygen absorbed" from permanganate *in 4 hours*, "oxygen absorbed" *in 4 hours* minus that absorbed *at once*, chlorine (minus the chlorine of the water supply), ammoniacal nitrogen, and organic nitrogen are given. Putting these figures into the form of curves it is seen :—

(*a*) that the *4 hours* "oxygen absorbed" curve runs comparatively evenly with the "strength" curve, excepting where the sewage is highly ammoniacal (as at Caterham and, in a lesser degree, at Andover), when the curves cross each other.

(*b*) The two curves for "oxygen absorbed" *in 4 hours* and for "oxygen absorbed" (*in 4 hours* minus *at once*) run practically parallel throughout, excepting in the few cases where the "oxygen arbsorbed" *at once* is either exceptionally high or exceptionally low.

(*c*) The curve for ammoniacal nitrogen bears no relation to that for "oxygen absorbed" *in 4 hours*, but the curve for organic nitrogen is to some extent of the same type as that for "oxygen absorbed."

(*d*) The curve for chlorine (after deducting the chlorine of the water supply) agrees sometimes with that for ammoniacal nitrogen, but bears no relation to the other curves.

The foregoing summary may be said to hold good, broadly, not merely for the domestic sewages examined, but also for those containing trade waste, excepting that in the latter case allowance may have to be made for any abnormality in the figure for "oxygen absorbed" *at once* or *in 3 minutes* (*cf.* p. 4). It may therefore be said that, in default of a determination of oxygen taken up from air or from water, and excepting in the case of a highly ammoniacal sewage, the two "oxygen absorbed" tests, taken together (using excess of strong permanganate), give a very fair indication of the nature and "strength" of a sewage ; but, of course, not such a good indication as when they are conjoined with a determination of the ammoniacal and organic nitrogen, when the ratios above mentioned can be calculated.

* Sixth Report of the Commission, Appendix III., p. 43.
† Fifth Report of the Commission, Appendices III. and IV.

TABLE B.

CRUDE SEWAGES (HOURLY SAMPLES).

	* Calculated Strength ÷ 10.†	"Oxygen absorbed" in 4 Hours.	"Oxygen absorbed" in 4 hours, minus at once.	Chlorine minus Chlorine in water supply.	Ammoniacal Nitrogen.	Organic Nitrogen.
(A) DOMESTIC OR MAINLY DOMESTIC.						
Clifton	24·7	26·1	20·2	8·07	3·82	2·26
Calverley (B)	24·5	29·6	22·1	14·4	11·82	2·98
Normanton	23·5	29·3	22·9	14·6	6·95	3·09
Little Drayton (B)	20·5	24·4	18·3	10·2	7·57	2·76
Caterham	19·5	18·0	12·3	12·2	13·41	3·87
Withnell (A)	17·4	21·2	16·3	8·3	5·35	2·67
Hampton	17·2	17·8	12·8	13·5	9·40	3·14
Accrington	12·1	13·5	10·5	—	5·18	2·13
Hendon - { High Level + Low Level }	11·0	13·1	9·7	—	3·6 ap.	2·0 ap.
Andover (A)	10·8	10·0	7·0	—	7·37	2·22
Newton (B)	10·6	12·3	9·2	9·9	4·3 ap. ‡	1·44 ‡
Chorley	10·6	12·2	9·2	7·2	3·96	1·91
Halton	10·3	11·8	9·3	6·7	4·74	1·05
Oswestry	9·9	11·3	8·4	8·6	3·53	2·25
Dorking (experimental)	9·6	10·0	7·6	—	4·65	1·92
Kingston	9·4	10·7	7·4	7·8	3·85	1·63
Ilford (experimental)	9·1	9·7	6·8	16·9	4·89	1·29
Horfield	8·8	9·4	6·5	5·4	3·80	2·19
Knowle	7·8	8·1	6·2	6·1	4·02	1·70
Exeter (St. Leonard's) (B)	6·0	4·4	3·3	5·0	2·86	0·87
Slaithwaite	4·1	4·6	3·4	3·9	1·66	0·89
Prestolee	2·6	3·6	2·8	1·37	0·42	0·27
(B) SEWAGES CONTAINING CONSIDERABLE OR MUCH TRADE WASTE.						
Rochdale	20·3	26·6	17·7	11·9	4·16	2·60
Guildford	19·4	22·0	17·0	—	7·39	3·95
Exeter (Main Works)	16·5	19·9	14·4	9·6	4·67	3·23
Maidstone	16·4	21·0	16·6	5·0	3·51	2·62
Hartley Wintney (B)	15·5	18·6	13·5	—	7·47	3·28
York	11·5	13·8	11·4	7·6	2·58	1·31

* Strength calculated from Formula in Column 9 of Table A.

† The actual figure has been divided by 10, in order to make the comparison with the "Oxygen absorbed" figure easy. ‡ Inferred.

TABLE C.

CALCULATED "STRENGTHS" OF SEWAGES, SEPTIC TANK LIQUORS, AND PRECIPITATION LIQUORS (HOURLY SAMPLES), ACCORDING TO FORMULA IN COLUMN 9 OF TABLE A.

	Crude Sewage.	Settled Sewage.	Septic Tank Liquor.	Precipitation Liquor.
(A) DOMESTIC OR MAINLY DOMESTIC.				
Clifton	247	123		
Calverley (B)	245	—	—	124
Normanton	235	—	—	112
Little Drayton (B)	205	165		
Caterham	195	—	161	
Withnell (A)	174	—	—	81
Hampton	172			
Accrington	121	—	92	
Hendon - { High Level + Low Level }	110			58
Andover (A)	108	—	90	—
Newton (B)	106	122		
Chorley	106	—	—	50
Halton	103	80		
Oswestry	99	91		
Dorking (Experimental)	95	80	82	{ 69 Al. F. 56 Al. F. + lime.
Kingston	94	—	—	51
Ilford (Experimental)	91			
Horfield	88	—	—	36
Knowle	78	—	58	
Exeter (St. Leonard's) (B)	60	—	41	
Slaithwaite	41	—	37	
Prestolee	26	—	22	
(B) CONTAINING CONSIDERABLE OR MUCH TRADE WASTE.				
Rochdale	203	—	83	77
Guildford	194	—	125	
Exeter (Main Works)	165	—	99	
Maidstone	164	—	—	88
Hartley Wintney (B)	155	—	{ 122 A = 108	
York	115	—	58	63

Table D. gives (1) the population draining to the various works; (2) gallons per head per day, and (3) gallons per head multiplied by calculated "strength." This last column ought in theory to give approximately the same values for domestic sewages, but it will be seen that the figures in it differ widely. As a rule those places with a small population and a small flow per head give a low figure for "aggregate strength." The high figures in this column for the places with large quantities of trade refuse in the sewage are very marked.

TABLE D.

	Population Draining to Works.	Gallons Per Head.	Gallons Per Head × Calculated Strength ÷ 100.*
(A) Domestic or Mainly Domestic Sewages.			
Clifton	2,000	11·0	27
Calverley (B)	2,300	5·2	13
Normanton	12,600	13·9	33
Little Drayton (B)	1,550	7·7	16
Caterham	1,300	13·0	25
Withnell (A)	1,650	9·0	16
Hampton	† 6,500	27·7	48
Accrington	† 46,300	25·4	31
Hendon {High Level + Low Level}	† 23,500	40·4	44
Andover (A)	† 5,000	30·0	24
Newton (B)	9,000	23·0	32
Chorley	† 27,000	33·0	35
Halton	2,000	17·5	18
Oswestry	† 9,800	35·7	34
Dorking (experimental)	—	—	
Kingston	† 53,450	51·4	48
Ilford (experimental)	—	—	—
Horfield	2,500	15·2	13
Knowle	† 1,600	25·6	20
Exeter (St. Leonard's) (B)	† 1,200	33·0	20
Slaithwaite	3 000	46·6	19
Prestolee	500	36·0	9
(B) Sewage Containing Considerable or much Trade Waste.			
Rochdale	52,000	25·2	51
Guildford	† 16,000	25·0	49
Exeter (Main Works)	† 38,000	34·0	56
Maidstone	† 34,000	44·1	72
Hartley Wintney (B)	† 1,600	28·0	43
York	(?) 80,000	53·0	61

Note. † Signifies that the whole of the population drains to the works.
* The actual figure obtained has been divided by 100 for simplicity.

Note:—A modification of the above formula, based upon experimental results, may also be applied to effluents, and in this way a figure may be obtained, showing approximately, in terms of dissolved oxygen used, the purification effected per cube yard of a given filter.

George McGowan.

February, 1907.

ADDENDUM.

Since the foregoing Memorandum was written, further determinations have been made of the absorption of dissolved oxygen by 2 samples of sewage, 2 of septic liquor, and 2 of precipitation liquor. The gases evolved during the aeration have been analysed in the case of 7 sewages, 7 septic tank liquors, and 3 precipitation liquors (most of which were included in the foregoing Memorandum, but without a correction being then made for the evolved gases).

The additional results obtained are not sufficient to justify any further detailed statement at this stage, but they suggest the modification of the "strength" formulæ, No. 1, somewhat as follows :—

For *Sewages*.	(Ammon. + Organic N.) × 4·5 + (Ox. abs. in 4 hrs. × 6·0).
For *Septic Liquors*.	,, ,, ,, + (,, ,, × 6·0).
For *Precipitation Liquors*.	,, ,, ,, + (,, ,, × 5·0 (?)).

The above are not yet, however, brought forward as alternative formulæ to those of No. 1 ; further data must be accumulated before any definite statement can be made. Still, so far as they go, they indicate that the No. 1 formulæ are probably not very far from the truth, though the multiplication factor for the 4 hours' "oxygen absorbed" figure is most likely a little too high for all three classes of sewage liquor.

G. McG.

August, 1909.

MEMORANDUM ON THE ESTIMATION OF THE WORK DONE BY SEWAGE FILTERS AND ON THE COMPARISON, IN THIS RESPECT, OF DIFFERENT TYPES OF FILTER TREATING DIFFERENT SEWAGE LIQUORS.

By Dr. G. McGowan and Mr. Colin C. Frye.

Introductory.

When one of us was discussing with Mr. Willis, Secretary to the Commission, the memorandum on "Strength of sewage," shortly after it was written, he suggested that it might be possible to make a rough comparison of the efficiency of different filters by subtracting from the four hours' "oxygen absorbed" figure of the sewage liquor treated the corresponding figure of the filter effluent, and multiplying the figure so obtained by the volume treated per cube yard per 24 hours. So far as our recollection goes, this was the germ from which the following paper was evolved.

With our present knowledge, we think that the best method of estimating the work done by a sewage filter is to determine the degree of oxidizability of the sewage liquor treated and that of the filter effluent obtained. The difference between the two represents the oxidation or—more correctly—the purification effected by the filter, which at the present time we may refer to as the "work done." Subsequent investigations may make it possible to differentiate quantitatively between the energy expended in the oxidation of (*a*) the carbon and (*b*) the nitrogen compounds of sewage or sewage liquor.

As our basis, we have in the first instance determined this oxidizability by Dr. Adeney's "Aeration" or "Dilution" method, viz., by mixing the sewage liquor or effluent with an excess of well-aerated tap water and estimating the oxygen in the mixture, both at the beginning and the end of the experiment, sufficient time being allowed for the oxidation of the organic impurity by the oxygen in solution in the water.

From the results of a number of such estimations, taken in conjunction with the ordinary figures of analysis of the effluent, we have been enabled to suggest in the following pages a formula on somewhat similar lines to that made use of by one of us for arriving at the "strength" of a sewage or sewage liquor (*cf.* memorandum on the measurement of the "strength" of sewage liquors, p. 5). By applying this formula, the degree of oxidizability of an effluent can be arrived at, after a simple analysis, with a fair degree of accuracy.

Oxidizability of Filter Effluents.

In the memorandum on the subject in this Appendix, the measurement of the "strength" of a sewage as affecting purification is discussed. The conclusion arrived at is that at the present time the strength of a sewage or sewage liquor can be best expressed and measured in terms of the amount of oxygen required for the complete or practically complete oxidation of its ammonia and organic matter. On page 4 of that memorandum, one or two simple formulæ, based upon experimental data, are given, by means of which the "strength," *i.e.*, the degree of oxidizability, of a sewage, septic tank liquor, or precipitation liquor, may be arrived at with a fair degree of accuracy in a short time; while Table C, on page 7, gives the calculated "strengths" of a number of the sewages, etc., which have been examined for the Commission. *The actual figures for "strength" represent parts by weight of oxygen required to oxidize* 100,000 *parts of sewage or other liquor.*

The same principle may be applied to estimating the degree of purity, or, more accurately, the degree of oxidation, of a filter effluent. Before proceeding to discuss this, however, it will be advisable to give some experimental data, showing to what extent eight effluents of known composition took up oxygen from excess of good tap water, when the mixture was kept for a lengthened period in a tightly stoppered bottle, with a mercury joint (*see* Table I). The oxygen in the dilute mixture was determined both at the beginning and at the end of the experiment, and also the oxygen in the small quantity of gas evolved from the liquid, which collected at the top of the bottle. Each experiment extended over a long period of time (116 to 349 days), so that we think it may be safely taken for granted, judging from other experiments on the same lines, that all or practically all the ammonia, and all excepting traces of very resistant organic matter, were oxidized in every case.

In addition to these eight effluents, the results are given of similar estimations with five others, but this time in unjointed bottles, the stoppers of which were to all appearance very good. These latter are only to be taken as supplementary to the former.

A. Effluent.	B. Ammoniacal Nitrogen.	C. Total Organic Nitrogen.	D. Nitric + Nitrous Nitrogen.	E. "Oxygen absorbed" from $\frac{N}{8}$ permanganate in 4 hours at 27°C. (80° F.)	F. Volatile matter in suspended solids.	G. Dilution with tap water (1 vol. effluent).	H. Length of time the dilutions were kept (days).	I. Dissolved oxygen used up. Parts by weight per 100,000 of effluent.	J. Ratio of 4 hours "Oxygen absorbed" to "x" oxygen.*	K Ratio of volatile solids to "x" oxygen.*
JOINTED SAMPLES.	*Parts per*	100,000.				Tap water Vols.				
ROCHDALE PERCOLATING FILTER EFFLUENTS.										
Settled effluent No. 3688 - - -	0·07	0·38	3·94	1·29	2·6	19	348	5·52	1 : 1·6	1 : 0·8
Do. paper-filtered - - - -	0·07	Probably about 0·3	3·85	0·91	0·0	9	349	2·54	1 : 1·0	
ACCRINGTON EXPERIMENTAL EFFLUENTS.										
Secondary contact effluent No. 464 -	1·92	0·71	0·64 (Nitrous nitrogen).	3·44	4·2	34	279	† about 20·0	† about 1 : 2·5	† about 1 : 2·0
Do. paper-filtered - - - -	1·78	0·42	1·30 (nearly all nitric nitrogen)	1·35	0·0	16	340	10·78	1 : 0·7	
Primary contact effluent No. 611 -	1·12	0·79	0·25	3 55	6·0	34	201	19·74	1 : 3·1	1 : 1·9
Do. paper-filtered - - - -	1·12	Say, 0·4	0·25	1·36	0·0	15	201	8·82	about 1 : 1·5	
Primary contact effluent (1 W) No. 615	0·55	0·36	0·38	1·27	1·5	15	201	8·24	1 : 3·2	1 : 2·8
Do. paper-filtered - - - -	0·55	Say, 0·25	0·38	0·86	0·0	9	201	5·68	1 : 2·4	
UNJOINTED SAMPLES.										
ROCHDALE PERCOLATING FILTER EFFLUENTS.										
Settled effluent No. 3694 - - -	0·14	Say, 0·35	2·0 ap. ‡	1·36	2·5	9	116	7·59	1 : 4·0	1 : 2·2
Paper-filtered effluent No. 3693 (corresponding to No. 3694) - - -	0·11	Say, 0·22	2·0	0·55	0·0	4	116	1·75	1 : 0·5	
ACCRINGTON EXPERIMENTAL EFFLUENTS.										
Percolation effluent No. 432 (B.W.), paper-filtered - - - - -			2·33	1·11	0·0	14	217	4·67		
Secondary contact effluent No. 440 (2 W.), paper-filtered - - - -			0·29	0·68	0·0	14	217	6·14		
KINGSTON.										
Primary contact (coke (?) bed) effluent, No. 751 - - - - - -	0·59	0·23	0·75	0·55	Say, 0·5	14	177	5·78	1 : 3·8	1 : 4·0 ap.

* By "x" oxygen is meant that portion of the dissolved oxygen which has been taken up by the organic matter of the effluent, after the oxygen required by the ammoniacal and organic nitrogen has been allowed for. † Owing to an accident, only an approximation can be given here. ‡ Ap.=Approximately.

The foregoing results are supplemented by one or two others later on, but we think that they may be safely taken in the meantime as confirming the points :—

(1) That a well-oxidized effluent (apart from suspended solids), in which the nitrogen is nearly all in the form of nitrate, takes up hardly any further oxygen from air or from water, practically all the carbonaceous as well as the nitrogenous matter having been already oxidized.*

(2) That a fairly well-oxidized effluent (apart from suspended solids), in which about one-third to one-half of the nitrogen present is in the form of nitrate, also takes up very little further oxygen, beyond what is required to oxidize its ammonia and organic nitrogen compounds.†

(3) That even in the case of a poorly oxidized effluent, containing only a little nitrate, the quantity of oxygen required to oxidize the residual organic matter (after the ammonia and organic nitrogen have been allowed for) is not great. Further data, however, are required here.

(4) That—as a rough approximation—1 part by weight of the volatile matter in the suspended solids present in a well or fairly well-purified effluent takes up about 2 parts by weight of oxygen. Further data are desirable here also, especially as regards the suspended solids of indifferently purified effluents, for it is obvious that such solids must vary to some extent as regards oxidizability.

In the meantime, therefore, we calculate the oxidizability of an effluent, *in parts by weight of oxygen per* 100,000 *of effluent,* by the formula :—

(Ammoniacal + organic nitrogen × 4·5)(1) **+ (Volatile matter of suspended solids × 2)**(2) **− (Nitric nitrogen × 3)**(3).

(1) The figure 4·5 is got from the molecular proportions :

$$\frac{O_2 \times 4}{N_2} = \frac{128}{28} = 4{\cdot}57.$$

(2) The figure 2 is an approximate deduction from the figures in Column K of Table I.

(3) The nitrate of an effluent represents a certain potential oxidizing power, and this is credited to the effluent in the above formula, in terms of oxygen, according to the molecular proportions : $N_2O_5 = N_2 : O_5 = 28 : 80 = 1 : 3$.

In Table II. (p. 30 *et seq.*), the calculated oxidizability of a large number of different effluents is given. Excepting in two instances out of about sixty, the amount of nitrite in the effluents cited was so small as to be negligible. In those two cases it was credited to the effluent by multiplying the figure for nitrous nitrogen by 1·7 ($N_2 : O_3 = 28 : 48 = 1 : 1{\cdot}7$).

In about seven cases of very poor and imperfectly oxidized effluents (from single contact), besides deducting the oxygen required to oxidize the ammoniacal and organic nitrogen and the volatile solids, a small further deduction has been made of a figure equivalent to the 4 *hours'* "oxygen absorbed" figure × 2. This has been done without having any real experimental basis to go upon, reliance being placed upon our general knowledge of the properties of such effluents ; it is to be regarded as a tentative correction, pending the accumulation of actual data.

Subsequent experimental work will no doubt modify to some extent the formula given above, for arriving at the oxidizability of an effluent, especially in those cases where indifferent effluents are in question.‡ At the same time, we think that it may be accepted for the present as giving a fair approximation to the truth, especially for well or fairly well-oxidized effluents.

We therefore apply this formula to an effluent, for the purpose of arriving at a figure which shall express approximately the "strength" or degree of oxidizability of that effluent.|| If this figure be deducted from the "strength" figure of the original sewage or sewage liquor from which the effluent was derived, the difference will represent, in terms of parts of oxygen per 100,000 of liquid, the purification effected.

Table II., p. 30 *et seq.*, which is sufficiently explained by the headings, gives the figures for relative purification *effected by* 1 *cube yard of filter* at nearly all the places which have been under observation for the Commission,§ and also at the experimental installations at Accrington and Dorking.¶ Excepting where it is otherwise stated, the calculation is

* Cf. the original work of Dr. Adeney upon this subject.

† For a modification of this statement, as regards organic nitrogen, cf. p. 148 *et seq.*

‡ Cf. p. 49.

§ Cf. Fifth Report, Appendix III.

|| Cf., however, the Addenda on pp. 44–51.

¶ Only the earlier Dorking results are included here ; the later ones are to be found in the Dorking Report by Mr. Richards (this Appendix, p 172).

based upon the hourly samples of sewage or other liquor treated upon the filter and the corresponding hourly samples of effluent. In those cases where, for one reason or another, no hourly samples of effluent were drawn, the comparison is made with chance samples of the effluent, but this is necessarily much less reliable, the number of chance samples not being very large.

In addition, a similar calculation has been made of the relative purification per cube yard effected at various places, from which the experimental data have been furnished to the Commission by the Local Authorities (Birmingham, Burnley, Heywood, Huddersfield, Leeds, Manchester, Oldham, and Sheffield), the calculations in nearly all those cases being based upon the analysis of *very large numbers* of chance samples of sewage liquor and effluent, extending over a year or more. Since "weak" permanganate is used at the above places for the oxygen absorbed tests, the calculated relative figures for purification per cube yard arrived at in this way can only be regarded as approximate.*

The various places may now be considered in more or less detail; they are grouped together according to the nature of the process followed.

Treatment of Crude or Settled Sewage upon Contact Beds.

(*Cf.* Table II, pp. 34–35.)

The principal results are as follows:—

Place.	Calculated Strength of Liquor.	Gallons treated per cube yard of filter.	Units of Purification per cube yard.	Percentage Purification:— (*a*) Whole Effluent.	(*c*) Effluent minus its Suspended Solids and Nitrate.	Age of Beds at time Average Samples were drawn (years).	Depth and Quality of Filtering Medium.
Double Contact.							
Withnell (crude) -	174	18·2	2,706	86	92	4	Primary, coarse, 5 feet; secondary, medium, 3 feet 6 inches.
Maidstone (crude)	164	23·7	3,775	97	96	5	Primary, coarse, 3 feet 4 inches; secondary, fine, 4 feet 4 inches.
Leeds (crude)	127	32	3,998	96	98	1½	Primary, coarse, 5 feet; secondary, medium, 6 feet.
Oswestry (partially settled).	91	41	3,538	95	94	about 4	Primary, medium to coarse, 4 feet 6 inches; secondary, medium, 4 feet 6 inches.
Halton (partially settled).	80	54 (d.w.f.) 106 (actual quantity)	3,737 7,335	87	89	2	Primary, coarse, 4 feet 3 inches; secondary, coarse, 3 feet 3 inches.
Sheffield (settled)	57·6	60	3,150	91	87	about 4	Primary, 3 feet, and secondary, 3 feet; both medium to fine.
Settled Sewage and Single Contact.							
Oldham (settled) -	51·1	73 (average quantity)	2,584	69	82	about 5	Medium to fine, 1 foot 6 inches to 3 feet.
Crude Sewage and Triple Contact.							
Hampton (crude) -	172	43	7,555	102	98	3	Primary, coarse, 4 feet; secondary, medium, 4 feet; tertiary, fine, 4 feet.

* In order to arrive at these approximate figures, we have multiplied by 1·6 the figures obtained at the places mentioned for "oxygen absorbed" in 4 hours from *weak*, *i.e.* ($\frac{N}{80}$) permanganate, to make them more or less comparable with our own figures obtained with *strong* ($\frac{N}{8}$) permanganate. This figure (1·6) was arrived at from some comparative estimations with weak and strong permanganate, but further analytical data are required for its verification or modification, especially as regards septic tank liquor.

If the work effected by 1 cube yard of filter at each of the six places treating sewage by double contact (Withnell, Maidstone, Leeds, Oswestry, Halton, and Sheffield) had been the same, and if it had been possible to obtain perfectly accurate experimental data for our calculation, the figures in column G of Table II for relative purification would have been identical. If, however, we consider the complex factors which enter into the case—especially the differences in strength of sewage and of volume treated, the comparison of effluents whose analysis was not all carried out upon the same plan, and the size and condition of the filtering material—we see at once that only an approximation can be hoped for.

Of the six installations treating crude or settled sewage upon double contact beds, Halton is not comparable with the others. There the process for part of the time was, practically speaking, single contact, on the secondary beds, of sewage which had been settled and then streamed through the primary.

At the other five places (Withnell, Maidstone, Leeds, Oswestry, and Sheffield), crude sewage was treated at the first three and settled sewage at the other two. The volumes treated, as given in column F of Table II, represent approximately *average* quantities, *i.e.*, the average volumes treated over the whole "life" of the beds. The volume given for Withnell (18·2 gallons) was the amount treated during the last $2\frac{1}{2}$ years of the "life" of the beds there, when they had an average capacity equal to only 50 per cent. of the original water capacity. To compare Withnell, therefore, with the other four places, which represent an *average* capacity of about 66 per cent.,* the figures for gallons treated per cube yard at Withnell and for units of purification would have to be multiplied by $\frac{66}{50}$. The calculated strengths of the sewages at the five places varied as much as from 174 at Withnell and 164 at Maidstone to 57·6 at Sheffield, but the units of purification per cube yard only varied between 2,706 and 3,998; or, excluding Withnell (where the effluent obtained was unsatisfactory), from 3,150 to 3,998. While, therefore, the strength varied from 3 to 1, the units of purification only varied proportionally from $1\frac{1}{3}$ to 1. The results from these four places, as regards work done, thus show a striking analogy.

The percentage purification, as judged by the atmospheric oxygen taken up in the process, † varied from 86 to 97, or again excluding Withnell, from 91 to 97. The percentage purifications—if we consider the effluent as without its suspended solids and nitrate—were 96, 98, 94, and 87. All four effluents were such as would be considered fair to good. The filter beds varied in depth from 3 ft. 3 in. to 6 ft., the primary being filled with coarse material and the secondary with material of medium size, excepting at Maidstone, where the material of the secondary beds was of fine grade.

Without attempting to draw too many conclusions from a small number of places, we think the inference is justified that from 3,000 to 4,000 units of purification per cube yard of filter per day may be looked for in the treatment of crude or partially settled sewage upon primary beds of coarse material, during their economic life, and secondary beds of medium to fine material, an effluent of fair to good quality being produced. The percentage purification, as judged by the atmospheric oxygen taken up in the process, would be from 90 upwards, including in the effluent its suspended solids and nitrate. If we exclude these, the percentage purification would usually be from 95 upwards. The percentage purification, as calculated on "oxygen absorbed" from permanganate in 4 hours, would be from about 83 upwards.

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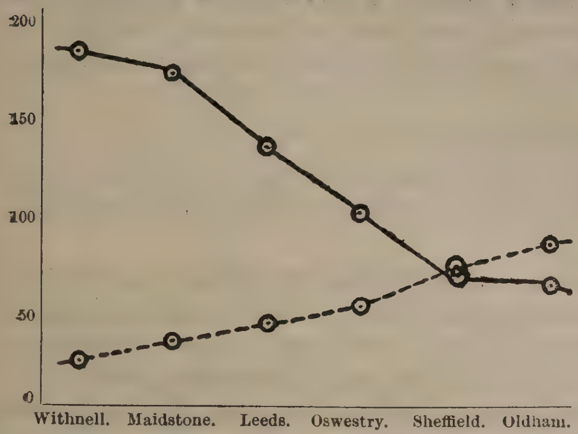
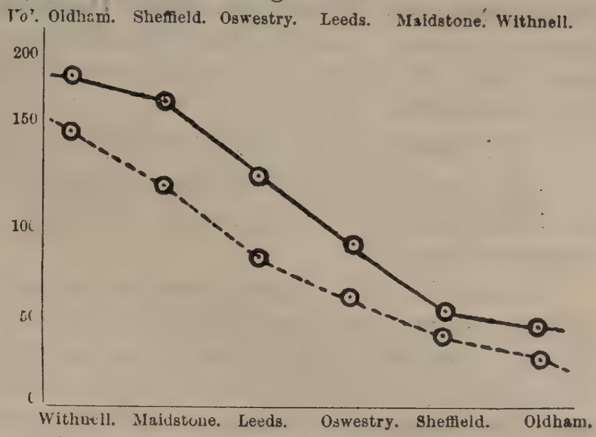
* A contact bed, when freshly filled with material, holds about 50 per cent. of water (unless the material is very fine, when it holds less). When the capacity is reduced to about 20 per cent., the material is usually in a very sodden and clogged condition. As the result of considerable experience, we put the average working capacity of a primary contact bed at 33 per cent. of its original empty tank capacity, or 66 per cent. of its original water capacity.

† These and subsequent figures for percentage purification are based on the (calculated) amount of atmospheric oxygen used in the filtration process for the oxidation of *both* the carbon and the nitrogen compounds present in the sewage liquor. If, theoretically, 100 parts by weight of oxygen are required by a given volume of sewage, for its conversion into a completely oxidized effluent, then "80 per cent. purification" means that 80 parts of atmospheric oxygen have been taken up.

The curves show graphically that the volumes of sewage treated at the various places were throughout in the inverse order of the calculated strengths.



Crude or Settled Sewage and Double Contact.
(Oldham = Single Contact.)
Calculated strength ————
Volume treated per cube yard - - - - - - - - -



Crude or Settled Sewage and Double Contact.
(Oldham = Single Contact.)
Calculated strength ————
Inverse volume per cube yard × 2 - - - - - - - -

The volume of sewage which can be successfully treated upon double contact beds, so as to produce a satisfactory effluent, therefore depends mainly upon its strength. Thus, 20 gallons of a strong sewage like that at Maidstone (strength 164) or 60 gallons of a rather weak sewage like that at Sheffield (strength 58 approx.), per cube yard per day, can be treated so as to give fair to good effluents (this, on the basis of an *average* bed capacity). With regard to the amount of suspended matter which can be put upon contact beds treating crude or settled sewage, *see* Fifth Report of the Commission, p. 48 *et seq.*

At *Oldham* a dilute settled sewage (approximate strength = 51) treated on *single* contact beds of rather fine to medium material, 1 ft. 6 in. to 3 ft. in depth, at the rate of 73 gallons per cube yard per day, gave 2,584 units of purification, or 69 per cent. purification on the original sewage. Fully two-thirds of the oxidizable matter was thus removed by single contact, a result in agreement with that from the Accrington experimental primary contact beds treating septic tank liquor (*cf.* Memorandum on the Accrington experiments, p. 56). In the case of a strong sewage containing much suspended solids, the figures for units of purification and percentage purification effected by a primary bed—worked within reasonable limits—would no doubt be greater than this, but the bed would lose correspondingly in capacity.

As regards *Hampton*, where crude sewage received at the time *triple contact* upon material varying from coarse to fine, a very high purification per cube yard is shown in column G of Table II, viz., 7,555 units, or 102 per cent. These figures, however, give an exaggerated estimate of the work actually done by the beds, because a large proportion of the organic solids of the Hampton sewage were at the time settled out in the "bays" of the primary filters, and it was impossible to draw samples of the actual settled sewage which was treated on the primary beds. It must also be borne in mind that the Hampton primary beds lost capacity very rapidly, showing that the purification was largely effected at the expense of capacity, owing to the relatively large volume treated upon these beds.

Treatment of Crude or Settled Sewage upon Percolating Filters.
(*Cf.* Table II., pp. 34–35).

The principal results are as follows :—

Place.	Calculated Strength of Liquor.	Gallons per Cube Yard.	Units of Purification per Cube Yard.	Percentage Purification :— (a) Whole Effluent.	(c) Effluent minus its Suspended Solids and Nitrate.	Depth and Quality of Filtering Medium.
Leeds (Ducat) (crude) -	172·6	25	4,373	101	99	Medium, 10 feet.
Little Drayton (B) (partially settled).	165	15·2	2,411	96	95	Medium, 7 feet 6 inches.
"Leeds" filter (crude) -	123	52	4,488	70	95	Very coarse, 11 feet 6 inches.
Clifton (partially settled)	123	15·6	1,828	95	96	Very fine to coarse, 4 feet.
Hendon (Ducat) (crude) -	107	40	3,964	93	92	Medium, 8 feet and 10 feet.
Dorking (Expl.) (settled)	80·1	120	8,556	88	89	Coarse, 6 feet.
Leeds (settled) - -	59·7	63	2,696	72	96	Coarse, 9 feet 6 inches.

Of the above seven installations, three treated crude and four settled sewage. The calculated strengths varied from 174 for the Leeds crude sewage, treated by the Ducat filter there, and 165 for the Little Drayton settled sewage, to 60 for the Leeds settled sewage. Some of the filters were of coarse material, and some of material of medium size, while at Clifton the surface material was composed of sand, overlying medium to coarse clinker.

The depth of the filters ranged from 4 feet to 11 feet 6 inches,

At Leeds, Hendon and Dorking the filters treated constant volumes of sewage, while at Clifton and Little Drayton the figures per gallon in column F of Table II, refer to dry-weather flow only.

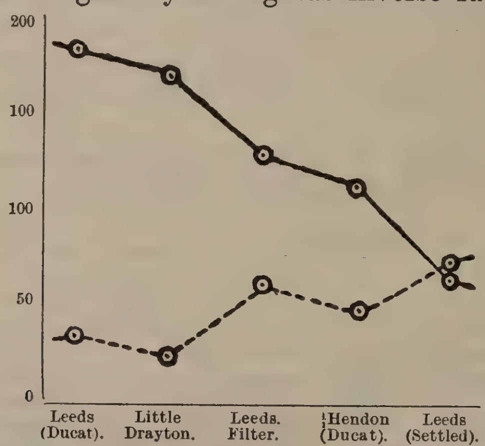
It will be seen from the table that, for the above seven places, the units of purification per cube yard varied from 1,828 to 8,556, or, excluding this last high figure, which was given by the Dorking experimental filter, from 1,828 to 4,488. The percentage purification, as judged by the atmospheric oxygen taken up in the process, varied from 70 to 101; or, if we consider the effluent without its suspended solids and nitrate, the percentage purification was from 92 to 99. As judged by the "oxygen absorbed" from permanganate in 4 hours, it varied from 70 to 98 on the whole effluent, including solids. The six effluents, apart from their suspended solids, were all good, the Leeds "Ducat filter" effluent being very good.

The conclusion is therefore justified that a percolating filter of coarse or medium-sized material, from 6 to 12 feet deep, treating either crude or partially settled sewage, will give from about 2,500 to 3,500 units of purification per cube yard per day, and produce a good effluent. If the sewage is well settled, up to 8,000 or 9,000 units of purification can be obtained (*cf.* Dorking Experiment, Table II).

In drawing this conclusion, we look upon the results from the "Leeds" filter and the Leeds Ducat filter as being too high, since the former became choked after a year's work, and the latter clogged on the surface after only a month. The Ducat filters at Hendon, treating a sewage of about average strength, have run for seven or eight years without any signs of clogging, but we think that our figure for volume treated there may be rather an over-estimate. Clifton stands in a different category to the other places, because of the very fine material of the filters there, and the constant scraping of the surface which is involved.

In the treatment of crude or settled sewage by percolating filters, we should expect considerable divergence in the results obtained, because in this process the rate of filtration is, to a great extent, dependent in practice upon the amount of suspended matter in the liquid treated. When much suspended solid is present, the rate of filtration is purposely slowed down, in order to prevent clogging, and this, of course, means that the filter is not then working up to its full power.

The volumes of sewage treated on the percolating filters at the above places (*see curve*) do not show the same regularity as regards inverse ratio that was found in the



Crude or Settled Sewage and Percolation.

Calculated strength ————

Volume treated per cube yard - - - - - - -

treatment of crude or settled sewage upon double contact beds; but, broadly speaking, the same conclusion holds good here also, viz., that the volume of sewage which can be treated upon a percolating filter depends *mainly* upon the strength of the sewage. We think, indeed, that it may safely be said to depend upon the strength of the sewage, provided that no secondary complications ensue through the choking of the filter, and also provided

that the filter is working up to its full power, or nearly so. Twenty to 25 gallons of sewage with a strength of 165 to 175, or 60 gallons of sewage with a strength of 60, can be treated per cube yard per day upon percolating filters of medium to coarse material, with the production of fair to good effluents.

The very high figure for units of purification given by the experimental filter at Dorking, treating well-settled sewage, was no doubt mainly due to the small quantity of suspended matter (6 to 7 parts) present in the liquor, and also to the fact that the effluent, while fair, was not a high-class one. The percentage purification was 88 for the whole effluent, and 89 for the effluent without the suspended solids and nitrate.

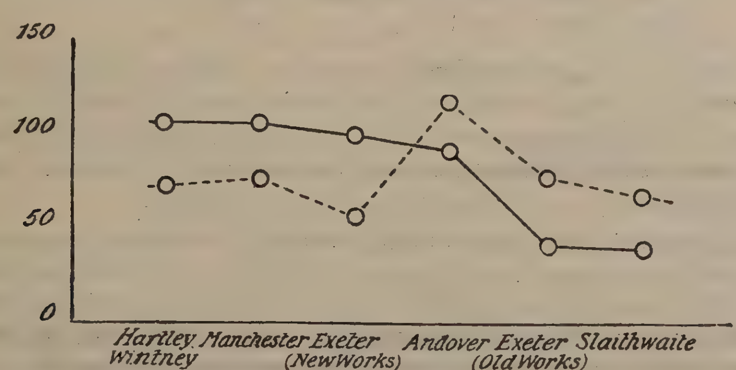
Treatment of Septic Tank Liquor upon Single Contact Beds.

Table II., pp. 36–39, gives the results from this process at Andover, Exeter Old Works, Exeter Main Works, Hartley Wintney, Manchester and Slaithwaite, besides those obtained in the Accrington Experiments I. and II. In drawing conclusions from them, however, we do not include Hartley Wintney, as at the time the various hourly samples were taken from that place, in January, 1904, the samples of effluent evidently did not give a true indication of the average working of the beds. The available data with regard to Manchester, also, only allow of our drawing approximate deductions as to the work done by the contact beds there.

The principal results are as follows :—

Place.	Calculated Strength of Liquor.	Gallons per Cube Yard.	Units of Purification per Cube Yard.	Percentage Purification :— (a) Whole Effluent.	Percentage Purification :— (c) Effluent minus its Suspended Solids and Nitrate.	Age of Beds at the time the Average Samples were drawn (years).	Depth and Quality of Filtering Medium.
Hartley Wintney -	108	73	7,264	92	93	3½	Medium to fine, 4 feet.
Manchester - -	106	77*	(a) 7,007 (b) 6,329	(a) 86 (b) 78	a) 92 b) 83		Medium, 3 feet 4 inches.
Exeter (Main Works)	99	55	3,729	68	64	1 to 2	Medium to coarse, 4 feet 6 inches.
Andover - - -	90	115	4,543	44	60	3	Medium to fine, 4 feet.
Exeter (Old Works) -	39	75 ap.	2,700	92	85	7	Medium to fine, 5 feet.
Slaithwaite - -	35·6	62†	1,817	82	83	4	Medium to coarse, 5 feet.

In three of the above cases—Hartley Wintney, Manchester and Andover, the volumes treated are almost inversely as the calculated strengths, while in the other three—Exeter Main Works, Exeter Old Works and Slaithwaite—the reverse is the case. These apparently contradictory results are no doubt mainly due to the fact that only in one case, Exeter Old Works, was a really good effluent obtained.



Septic Liquor and Single Contact.
Calculated strength ————
Volume treated per cube yard ---------

* Average quantity. † Constant quantity.

It will be noted that the purification effected per cube yard at the Exeter Main Works, Andover, and Exeter Old Works, in beds from 4 feet to 5 feet deep, varied between 2,700 and 4,543 units. At Manchester the beds probably effected a purification of about 6,000 units. At Slaithwaite the figure for units of purification (1,817) was a very low one, probably because the material was too coarse to make a good effluent possible, while at the same time the beds could probably have treated considerably more septic tank liquor and yet have given the same percentage purification, *i.e.*, they could have oxidized much more carbonaceous matter than they were actually called upon to do.

It is interesting here to compare the results obtained at Exeter Main Works, Andover, and Exeter Old Works, the first two treating strong tank liquors, with about 12 parts of suspended solids, and the last a weak tank liquor, with about 8 parts of suspended solids. The purification effected (2,700 to 4,543 units) was sufficient to change the dilute liquor at the Exeter Old Works into a good or fairly good effluent, the percentage purification (*a*), as judged by the atmospheric oxygen taken up, being 92 per cent., or (*c*), taking the effluent without its suspended solids and nitrate, 82 per cent. On the other hand, the purification was only sufficient to give a poor effluent from the strong liquor of the Exeter Main Works (percentage = (*a*) 68 per cent.; (*c*) 64 per cent.), and a very poor effluent from the strong liquor at Andover (percentage = (*a*) 44 per cent.; (*c*) 60 per cent.).

From these results we draw the conclusion that primary beds of medium to coarse or medium to fine material, 4 feet to 5 feet deep, will treat either a dilute or a strong septic tank liquor, so as to give from 3,000 to 4,500 units of purification per day. If the tank liquor is a very weak one and the material of the bed fine, this purification will be sufficient to produce a good or fairly good effluent, but, with a liquor of average or above average strength, a poor effluent will be obtained. Even a weak septic tank liquor will not give a fair or a good effluent by single contact, unless the material of the bed is fine, *i.e.*, unless it has a large internal surface area. This was well exemplified in the different results obtained at Exeter Old Works and Slaithwaite, where tank liquors of about the same strength were dealt with (the volume treated being greater at Exeter), but where the size of the material in the beds differed.

As a contact bed loses capacity, the figure for absolute units of purification must go down, though at a certain stage—assuming that the bed does not become clogged—this loss will probably be compensated to some extent by increased efficiency, through the enlargement of the internal surface area of the bed. At the same time it will be remembered that the efficiency of the experimental contact beds at Accrington, in proportion to their capacity per cube yard, remained the same in Experiments I. and II. (*cf.* this Appendix, p. 62).

Accrington Experimental Beds.—The results obtained from the experimental primary contact beds at Accrington are detailed at some length in the separate Memorandum on the subject. These beds were 3 feet deep and were filled with medium to coarse material.

In Experiment I the bed treating strong liquor gave 7,248, and that treating weak liquor 7,380 units of purification, with a loss of water capacity in 13 months of 37 per cent. and 34 per cent. respectively. The percentage purifications were :—

Strong liquor (*a*) 59 per cent. (*c*) 70 per cent.
Weak liquor (*a*) 60 ,, ,, (*c*) 74 ,, ,,

In Experiment II the units of purification were 4,944 and 3,022,* and the percentage purification :—

Strong liquor (*a*) 58 per cent. (*c*) 72 per cent.
Weak liquor (*a*) 62 ,, ,, (*c*) 73 ,, ,,

A primary contact bed can thus for a year give 7,000 to 8,000 units of purification per cube yard, treating a septic tank liquor of over average strength and with 14 parts of suspended solids, at an average rate of 144 gallons per day, or a liquor of about half this strength at a rate of 298 gallons per day, but the loss of capacity is very rapid and the effluent is of poor quality, *i.e.*, it is only partially oxidized.

Regarding this process from the point of view of a complete process, therefore, it is obvious that it could only be adopted for the treatment of weak septic tank liquors. For such liquors, with a strength, say, of 30 to 50, and containing not more than 6 to 8 parts of suspended solids, about 100 to 150 gallons per cube yard could be treated, with two or three fillings per day, and a non-putrescible effluent of fair quality produced. This

* In this last case the organic impurity put upon the weak liquor bed was only half that put on the strong.

estimate is made on the basis of an *average* capacity, throughout the "life" of the bed, of 66 per cent. of the original water capacity, or 33 per cent. of the original empty tank capacity. Such beds might be expected to last for 4 to 6 years.

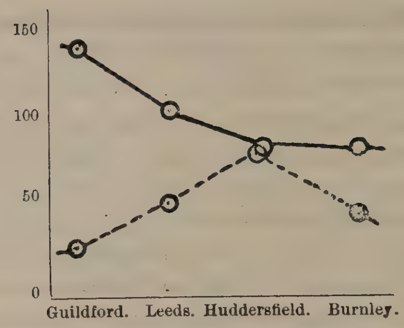
Manchester.—Our calculation of the work done by the Manchester contact beds can only be taken as approximate, because the tarry nature of the sewage and tank liquor there may to some extent have invalidated our calculation for "strength." In order to speak with confidence, we should require to fully examine a number of samples of the tank liquor. Subject to this, the absolute purification effected by the primary beds at Manchester in 1903–4 was high—about 6,000 to 7,000 units—the beds being of different ages and treating a strong tank liquor containing 11 parts of suspended solids; but the percentage purification was rather low—probably about 80 to 85. Manchester may therefore be regarded as an instance of a high absolute purification as regards carbonaceous matter, but with the purification not carried far enough to produce an effluent of high quality. The attention paid to the beds no doubt enables the maximum work to be got from them.

Treatment of Septic Tank Liquor upon Double Contact Beds.

In Table II., pp. 38–39, the results are given of the treatment of septic tank liquor upon double contact beds at Guildford, Leeds, Huddersfield, and Burnley, and also in the Accrington Experiments I and II, which have been already referred to. The main results are as follows :—

Place.	Calculated Strength of Liquor.	Gallons per Cube Yard.	Units of Purification per Cube Yard.	Percentage Purification :— (a) Whole Effluent.	(c) Effluent minus its Suspended Solids and Nitrate.	Age of Primary Beds (years).	Depth and Quality of Filtering Medium.
Guildford	125	22·7	2,697	95	94	2 to 4	Primary, 2 feet 6 inches, medium to coarse; secondary, 2 feet 6 inches, medium to fine.
Leeds	92·4	45	4,298	103	98	First 3 years.	Primary, 5 feet 6 inches, fine to medium; secondary, 6 feet, medium.
Huddersfield) Experimental).	77·1	76	5,624	96	97	First 4 years.	Primary, 3 feet 9 inches, coarse; secondary, 2 feet 11 inches, medium.
Burnley	74·1	40	3,004	101	98	4	Primary, 3 feet, coarse; secondary, 3 feet, fine.
Accrington Experiment I. (Strong liquor).	85·7	72·2	5,011	81	88	First year.	Primary, 3 feet, medium to coarse; secondary, 3 feet, fine.
Accrington Experiment I. (Weak liquor).	43·0	148·8	5,654	91	91	First year.	Primary, 3 feet, medium to coarse; secondary, 3 feet, fine.
Accrington Experiment II. (Strong liquor).	83·3	51·6	3,576	83	91	Second year.	Primary, 3 feet, medium to coarse; secondary, 3 feet, fine.
Accrington Experiment II. (Weak liquor).	42·2	57·9	2,200	90	92	Second year.	Primary, 3 feet, medium to coarse; secondary, 3 feet, fine.

Excepting in the case of Burnley, where the beds were evidently working well within their powers, the volumes treated per cube yard at the first four places are *roughly* in the inverse order of the strengths of the liquors, none of which were weak (strength = 74 to 125) (*see* curves).



Septic Liquor and Double Contact.

Calculated strength ————

Volume treated per cube yard - - - - - -

At Guildford the tank liquor was exceptionally strong, and, moreover, it contained a large quantity of brewery refuse. Hence, the actual figure for units of purification is rather low there, an effluent of moderate quality being produced. The beds at Guildford are only 2 feet 6 inches deep.

The *Accrington* experiments showed how rapidly the *aggregate purification* by double contact declined as the beds lost their capacity. Omitting from our calculations the results from the treatment of weak liquor in the Accrington Experiment II, when the beds were not working up to their full power, we think that the figures given in the preceding table show that from 3,500 to 4,500 units of purification per cube yard may be expected from double contact beds treating septic tank liquor, with the production of fair to good effluents. The percentage purification, as judged by the atmospheric oxygen taken up in the process, would be from 80 to over 100; excluding suspended solids and nitrate from the effluent, the percentage purification would be from 88 to 98. The percentage purification, as calculated on "oxygen absorbed" from permanganate in 4 hours, would be from 65 to 93.

Here, again, the volume of a septic tank liquor which can be successfully treated upon double contact beds *depends mainly upon its strength*, but the less suspended and colloidal solids the liquor contains, the longer will the beds retain their capacity; in other words, they will continue to give a greater aggregate purification per cube yard.

Thus, a strong liquor (strength 90) might be treated at a rate of 50 gallons per cube yard per day (equivalent to about two fillings per day); a medium liquor (strength 70) at a rate of 70 gallons (two to three fillings per day); and a weak liquor (strength 40) at a rate of 100 gallons (equivalent to about four fillings per day).

The amount of suspended matter in the tank liquor, however, is also of the first importance here. Thus, a weak liquor (strength 40) could not be treated at the rate of four fillings per day, if the suspended matter in it were more than, say, 4 parts per 100,000. (For details regarding this point, *cf.* Fifth Report of the Commission, p. 48.)

Treatment of Septic Tank Liquor upon Percolating Filters.

(*Cf.* Table II., pp. 40–41.)

Of the sixteen examples of the treatment of septic tank liquor upon percolating filters, six refer to the Commission's experimental installation at Accrington, and one each to the experimental installations at Guildford and Dorking. The remaining eight comprise four installations which have been under observation for the Commission, and three others from which the experimental data have been furnished by the Local Authorities.

Excepting at Caterham and Birmingham, where the filtering material was medium to coarse, and at Prestolee, where it was fine, the filters were all of coarse material.

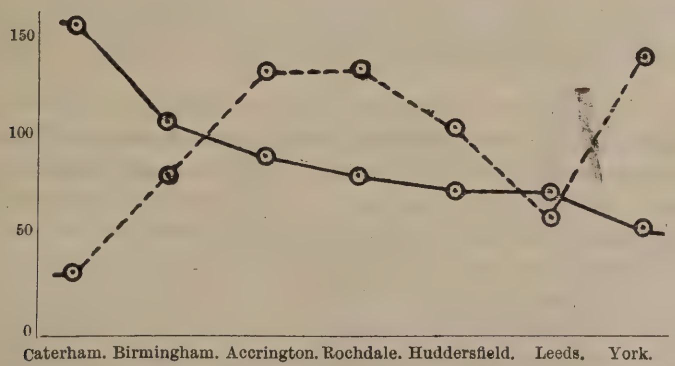
Omitting for the moment the results obtained from Prestolee and from the weak liquor in Accrington Experiment II, in both of which cases the filters were treating much less than they might have done, the units of purification per cube yard varied in the remaining fourteen instances from 4,322 at Leeds to 11,125 at Rochdale.

The results obtained at the last eight places may be conveniently compared, thus :—

Place.	Calculated Strength of Liquor treated.	Gallons per Cube Yard.	Units of Purification per Cube Yard per 24 hours.	Percentage Purification :— (a) Whole Effluent.	Percentage Purification :— (c) Effluent minus its Suspended Solids and Nitrate.	Depth and Quality of Filtering Medium.
Caterham -	161	31	4,557	91	79	Medium to coarse, 5 feet.
Birmingham -	113	83	7,656	82	86	Medium to coarse, 6 feet to 7 feet.
Accrington (whole works)	94	140	9,184	70	85	Coarse, 7 feet to 9 feet.
Rochdale -	83	141	11,125	95	95	Coarse, 9 feet.
Huddersfield -	77	110	6,897	81	97	Coarse, 7 feet.
Leeds - -	76	63	4,322	90	95	Coarse, 9 feet 6 inches.
York - -	58	150	9,225	106	98	Coarse, 6 feet 6 inches to 7 feet 8 inches.
Prestolee -	22	46	1,012	100	95	Fine, 5 feet.

The calculated "strengths" of the liquors treated varied from 161 at Caterham to 22 at Prestolee. After Birmingham, which gave the second strongest liquor (strength 113), there was a fairly gradual fall in strength throughout.

The curve representing volumes treated at the six sewage works of Accrington, Birmingham, Huddersfield, Leeds, Rochdale, and York bears an approximate relation to the inverse curve of strength, excepting in the case of Leeds and Huddersfield (*see* curve below).



Septic Liquor and Percolation.

Calculated strength ————

Volume treated per cube yard - - - - - - - - -

At Leeds the purification effected was much less than at the other five places, because the filter was not working up to its full power. Still, it was receiving tank liquor containing about 18 parts of suspended solids, of a rather fibrous nature, and this was evidently the reason why the average volume treated did not exceed 63 gallons per cube yard. At the other five installations, treating liquor varying in strength from 58 to 113, the units of purification per cube yard ranged from 6,897 to 11,125; the percentage purification, as judged from the amount of atmospheric oxygen used up, from 70 to 106; the percentage purification, disregarding the suspended matter and the nitrate in the

effluent, from 15 to 98; and the percentage purification on "oxygen absorbed" from permanganate in 4 hours, from 62 to 84. At all those places non-putrescible effluents of fair to very good quality were obtained.

The results obtained from the experimental stations were :—

Place.	Strength of Liquor Treated.	Gallons per Cube Yard.	Units of Purification per Cube Yard per 24 Hours.	Percentage Purification :—		Depth and Quality of Filtering Medium.
				(a) Whole Effluent.	(c) Effluent minus Suspended Solids and Nitrate.	
Guildford - - - -	90·3	50	4,275	95	95	Coarse, 6 feet
Accrington Experiment I. (Strong liquor).	85·2	100	7,310	86	90	" "
Dorking - - - -	81·6	120	8,448	86	86	" "
Accrington Experiment II. (Strong liquor).	81·2	100	8,440	104	96	" "
Accrington Experiment III. (Strong liquor).	73·2	125	8,050	88	93	" "
Accrington Experiment I. (Weak liquor).	48·0	200	7,680	80	86	" "
Accrington Experiment III. (Weak liquor).	40·7	250	9,225	91	93	" "
Accrington Experiment II. (Weak liquor).	40·5	100	4,120	102	94	" "

At Guildford the experimental filter was working well within its limits, and could probably have done considerably more. In the other five experiments, the variation in units of purification was only between 7,310 and 8,448. The percentage purification for the effluent as a whole varied from 80 to 104, and the percentage purification, eliminating suspended solids and nitrate, from 80 to 96.

From all the foregoing results—both on a large scale and experimental—the conclusion may be drawn that a percolating filter of coarse, or of medium to coarse material, and from 6 feet to 9 feet in depth, may be expected to give from 7,000 to 11,000 units of purification per cube yard when treating tank liquors varying in strength from 58 to 113, and to yield good effluents showing from 85 per cent. to 98 per cent. purification, considering the effluent as without its suspended solids and nitrate. Within the above limits, the less coarse the material, provided it can allow the free passage of the effluent suspended solids through it, and the deeper the filter, the greater is the relative purification effected per cube yard of filtering material.

The Accrington Experiment I showed that within the limits of volume treated, good effluents being obtained, pretty much the same amount of work is done per cube yard, whether one volume of strong liquor or two volumes of weak liquor are dealt with. *Other things being equal, therefore, the volume of septic tank liquor which can be treated upon a percolating filter of coarse material depends upon the strength of the liquor.* When much mixed trade effluent containing iron is present, as at Leeds and Birmingham, or much brewery refuse, as at Guildford, apparently less can be treated, proportionately, than in the case of a septic tank liquor from a domestic sewage. At Leeds, also, the fibrous character of the suspended matter makes it advisable to keep the rate of filtration low, in order to prevent clogging. The trade refuse at Rochdale, which contains much nitrogenous matter from wool washing and which is highly alkaline, does not render the septic tank liquor difficult of treatment.

Thus, about 80 gallons per cube yard of a strong septic tank liquor (strength = 113), 100 gallons of a liquor of about average strength (strength = 80), or 150 gallons of a rather weak liquor (strength = 58), can be properly dealt with upon deep percolating filters of coarse material.

Caterham.—The sewage and septic tank liquor at Caterham are altogether exceptional as regards the high proportion of ammonia and other nitrogenous matter present in them. So far as can be judged from the results obtained with the 5-foot filters there, such a septic tank liquor is more difficult or takes longer to oxidize than a proportionate volume of liquor

from an average domestic sewage ; hence, a less figure than the average, for units of purification per cube yard, is obtained at Caterham.

Prestolee.—The fine-grained filters at Prestolee were working greatly under their limit, having only 46 gallons per cube yard of an exceptionally dilute septic tank liquor to deal with. The result was the production of an exceptionally good effluent, but only 1,012 units of purification were effected per cube yard of filter.

Treatment of Precipitation Liquor upon Single Contact Beds.

(Cf. Table II., pp. 42–43.)

The examples of this method of treatment which have been under observation are Calverley, Heywood, and Kingston-on-Thames. The results are tabulated in Table II., but the chief items may be given again here :—

Place.	Calculated Strength of Liquor.	Gallons per Cube Yard.	Units of Purification per Cube Yard.	Percentage Purification :— (a) Whole Effluent.	(c) Effluent minus its Suspended Solids and Nitrate.	Age of beds.	Depth and Quality of Filtering Medium.
Calverley -	124	60 (?)	5,448 (?)	73	82	9 years.	Coarse to fine, 3 feet.
Kingston (Experimental).	51	250	10,825	85	81	Half of the material 3 years and half 6 years.	Medium to coarse, 3 feet.
Heywood -	40·2 (?)*	173	5,052 (?)	73	75	5 years.	Very fine to coarse, 4 feet 3 inches.

The data from Calverley and Heywood are not sufficient to warrant many deductions. At Calverley the volume of liquor treated and the units of purification obtained are probably much greater than they appear in the above table. The Calverley effluent is poor and the Heywood effluent evidently not very good, the percentage purification being low in both cases.

At Kingston a large volume of exceptionally well-clarified liquor, of about average or rather under average strength, is treated upon an experimental coke bed, 3 feet deep and of medium to coarse material. This results in a very high figure for units of purification (10,825), and an effluent of fair to good quality, but the percentage purification is rather low, viz. : (*a*) 85, or (*c*)—eliminating suspended solids and nitrate—81 per cent., owing to about two-thirds of the nitrogen left in the effluent being in the unoxidized state.

Although our data from Calverley, where the sewage is strong, and from Heywood, where the sewage is of about average strength, lack completeness, we think they are sufficient to show that—as in the case of settled sewage and septic tank liquor—single contact of precipitation liquor from such sewages is not sufficient to produce a good effluent.

With regard to Kingston, it is because of the excellent precipitation there that such a large volume as 250 gallons per cube yard can be treated. As stated, however, the effluent, while well oxidized as regards carbonaceous matter, has two-thirds of the nitrogen which remains in it in the unoxidized state, the nitrification not having been carried so far as it might have been.

We conclude, therefore, that 250 gallons per cube yard per day of a very good precipitation liquor of about average strength (strength = 50), equivalent to about four fillings per day, is somewhere about the maximum that can be dealt with by single contact, so as to produce a non-putrescible effluent of fair to good quality. From our capacity measure-

* From our general knowledge of the Heywood precipitation liquor, we think that it is really stronger than the above figure indicates, since it is derived from a fairly strong sewage.

ments at Kingston, we should estimate the probable life of such a bed, receiving four fillings per day of this well-clarified liquor, at about eight years or even more. With a more dilute tank liquor (strength, say, 30), possibly up to 350 gallons per cube yard, or about six fillings per day, could be managed, though it is doubtful whether such frequent fillings would be practicable on a large scale for any length of time.

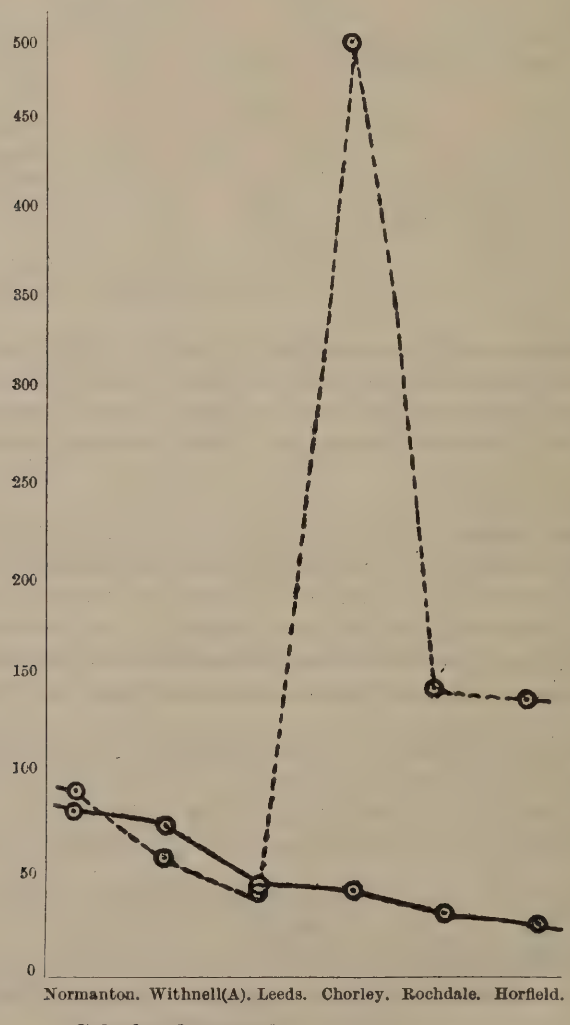
Treatment of Precipitation Liquor upon Percolating Filters.

(Cf. Table II., pp. 42–43.)

The data obtained with regard to this process are from Normanton, Withnell, Rochdale, Leeds, Chorley and Horfield, and from the earlier experiments of the Commission at Dorking.

The calculated strengths of the liquors treated varied from 92 at Normanton to 36 at Horfield.

The curve representing volume treated per cube yard of filter cannot in this case be said to bear an inverse ratio to that representing strength of liquor (*see* curve). The reason for this is that the suspended solids can be reduced in precipitation liquor to a



very low figure, and therefore very fine material may be used for the filtration of large volumes of liquor (*cf.* p. 26). With material of a given size, the two curves would no doubt bear an inverse relation to one another (*cf.* Accrington Experiment I.).

The principal results obtained are as follows :—

Place.	Calculated Strength of Liquor treated.	Gallons per Cube Yard.	Units of Purification per Cube Yard.	Percentage Purification :— (a) Whole Effluent.	(c) Effluent minus its Suspended Solids and Nitrate.	Depth and Quality of Filtering Medium.
Normanton - -	92	98	8,036	89	85	Very fine to coarse, 3 feet 3 inches.
Withnell (A) -	81	63 5	4,553	89	81	Very fine to coarse, 3 feet 3 inches.
Dorking (A) -	68·8	120	6,084	74	79	Coarse, 6 feet.
Dorking (B) -	55·3	175	9,065	94	89	Coarse, 6 feet.
Dorking (C) -	54·3	211	10,845	93	88	Coarse, 6 feet.
Leeds - - -	51·8	50	2,610	101	96	Coarse, 6 feet.
Chorley - -	50	500	24,550	98	87	Very fine to coarse, 3 feet.
Rochdale - -	39	157	5,228	85	92	Coarse, 9 feet.
Horfield - -	36	151	4,530	83	75	Coarse, 7 feet 6 inches.
Withnell (X) -	29·8	63·5	1,892	100	96	Very fine to coarse, 3 feet 3 inches.

The above installations may, for purposes of comparison, be conveniently divided into two sets, the first comprising Normanton, Withnell, and Chorley, where the beds are shallow and constructed of very fine to coarse material, graded, and the second set Dorking (experimental), Rochdale, Leeds, and Horfield, with deep beds constructed of coarse material.

At Normanton, Withnell, and Chorley the "International" process, more or less modified, is carried out. The precipitation liquors at Normanton and Withnell are very strong, and only moderately clarified in the case of Normanton (suspended solids = 14), while at Chorley the liquor is of only average or less than average strength and extremely well clarified (suspended solids = about 3). The exceptional amount of work done by the filters at Chorley, viz., 24,550 units per cube yard when the hourly samples were drawn and about 17,000 to 18,000 units on a general average, is much beyond that obtained at any other installation, being partly the result of the straining action of the fine material upon the suspended and colloidal matter of the liquor, and partly the result of the oxidation going on in the filter (we have not yet got the necessary data for differentiating between these actions). The effluent is a good one, being clear and non-putrescible and taking up dissolved oxygen from water only very slowly. The figures for percentage purification—(*a*) 98 for the effluent as a whole and (*c*) 87 apart from its suspended solids and nitrate—show, however, that there was still an appreciable quantity of unoxidized nitrogen left in the hourly samples of effluent ; in other words, the second or nitrification stage of the oxidation was not carried quite to its limit.

At Normanton 8,036 units of purification per cube yard were obtained, with the production of a very fair effluent of the same type as that at Chorley, though, owing to the method of working the filters by continuous ponding, the oxidation was not carried quite so far (percentage purification = (*a*) 89 per cent., (*c*) 85 per cent.). The same remarks apply to the Withnell effluent (*A*), where 4,553 units of purification were obtained ; the data from Withnell are, however, not sufficient to allow of generalisation.

At Leeds, Rochdale, and Horfield, with deep filters of coarse material treating precipitation liquor varying in strength from 52 to 36, the results were more or less analogous. Leeds was under-treating in dry weather (with the object of overtaking large flows in time of storm), with only 50 gallons per cube yard per day of a precipitation liquor of about average strength. The units of purification were only 2,610, but on the other hand the effluent obtained was very good (percentage purification = (*a*) 101, (*c*) 96).

Rochdale, treating a somewhat dilute liquor (strength = 39) at the rate of 157 gallons per cube yard per day, and giving 5,228 units of purification, was also not working up to its full power. The effluent obtained was of good quality, apart from its suspended solids, the figures for percentage purification being (*a*) 85 and (*c*) 92.

Horfield, treating 151 gallons per cube yard of a weak precipitation liquor (strength = 36), gave 4,530 units of purification and a very fair effluent, but the percentage purification was not high, viz. :—(*a*) 83, (*c*) 75. As at Leeds, however, very largely increased volumes are treated at Horfield in times of storm.

The Dorking experiments with precipitation liquor were interesting. In Experiment I the working of the filter—at that time not quite mature and treating a fairly strong liquor, not very well clarified (suspended solids = 8)—was considerably interfered with by surface growths. During Experiments II and III the filter was mature, and the liquor treated, which was of average strength, was better clarified (suspended solids = 6 and 5, respectively). The results were :—

(II.) 9,152 units of purification, with percentage purification (*a*) 94, (*c*) 89.

(III.) 10,941 units, with percentage purification (*a*) 93 ; (*c*) 88.

In both the two last cases the effluents were very fair.

The foregoing results, therefore, emphasise very strongly the fact that, within limits, the finer the material of a filter, the greater is the amount of oxidizing work which can be obtained from it. If, however, fine material is to be used, it is necessary that the liquor under treatment shall be very well clarified, while at the same time much labour has to be expended in keeping the surface of a fine-grained filter in working order. When very large quantities of liquor are treated in this way, the nitrification of the effluent is not carried quite to its limit. It must also be pointed out that it is only under favourable conditions that such a well-clarified liquor as that at Chorley can be produced ; thus, the sewage has to be of average or under average strength, and large quantities of precipitant have to be added, unless quiescent settlement can be given.

From the above results we draw the following broad conclusions :—

(1) *The volume of precipitation liquor which can be treated upon filters of coarse material depends mainly upon the strength of the liquor.*

(2) *The volume which can be treated upon filters of fine material depends not merely upon the strength but also upon the degree of clarification of the liquor.*

For deep filters of coarse material, about 150 gallons of liquor of average strength (strength = 50 to 60), or 200 to 250 gallons of weak liquor (strength = 30 to 40), can be treated per cube yard per day, with the production of a fair to good effluent. We have no data with regard to the filtration of a *very strong* precipitation liquor through percolating filters of coarse material, but probably such a liquor could be treated successfully at the rate of 75 to 100 gallons per cube yard per day.

Shallow filters of fine material.—From very strong sewages it is difficult to obtain a thoroughly well-clarified precipitation liquor ; for this reason percolation through fine material is probably inadvisable in such cases, though the results obtained at Normanton show that, on a small scale and with a constant flow, 100 gallons per cube yard per day of a strong liquor (strength = 92) can be treated in this way so as to yield a very fair effluent. With a clear liquor of average or under average strength (strength = about 50), 300 to 400 gallons per cube yard per day can be successfully treated upon shallow percolating filters of fine material.

We have no actual data with regard to the filtration of *very weak* precipitation liquor. Although, in theory, a relatively—or more than relatively—larger volume of this could be treated on fine-grained shallow filters, we think that in actual practice it would probably be found difficult to get much more than 500 gallons per cube yard through the filtering material in one day. If, to meet this difficulty, the filter were made coarser-grained, its internal surface area would be lessened and—with this—the amount of purification which it could effect.

SUMMARY.

It may be convenient if some of the chief points in this Memorandum are summarized :—

1.—In order to measure the work done by a biological filter, we determine the "strength" or oxidizability of the sewage or sewage liquor going on to it, and of the effluent coming out. The difference between the two represents the purification effected by the filter (p. 10).

2.—The oxidizability of an effluent (which can be estimated exactly by Dr. Adeney's "aeration" method)—at all events of an effluent which is fairly well purified—can be arrived at pretty accurately, after a simple analysis, by the application of the formula:—(ammoniacal + organic nitrogen × 4·5) + (volatile matter of suspended solids × 2) − (nitric nitrogen × 3).

The figure so obtained represents the number of parts by weight of oxygen which are still required to fully oxidize 100,000 parts of effluent (p. 12).

3.—We use the term "units of purification" as giving an (approximately) quantitative measurement of the work done by a filter. The number of units of purification is obtained by deducting from the "strength" figure of the sewage or sewage liquor passing on to the filter the "strength" or oxidizability figure of the effluent, and multiplying the figure so obtained, which represents the amount of oxygen used up, by the number of gallons treated per cube yard of filter per day* (dry-weather flow or constant flow, as the case may be).† It must however be clearly understood that this proposal is only meant to apply to the case of good, or at all events fairly good, effluents. In the case of a bad effluent it may be misleading, for, as a general rule, the more sewage liquor passed through a filter with a poor result, the greater the number of units of purification by this method of calculation.

4. *Treatment of Crude or Partially Settled Sewage upon Double Contact Beds.*—The volume of sewage which can be treated by double contact, so as to give a fair or good effluent, varies almost inversely as the "strength," *e.g.*, 24 gallons per cube yard per day of sewage with a strength of 164, or 58 gallons of sewage with a strength of 60. During the "economic life" of the beds, an average of 3,000 to 4,000 units of purification per cube yard of filter per day may be looked for in the treatment of crude or settled sewage upon primary beds of coarse material and secondary beds of fine material, an effluent of fair to good quality being produced (p. 14).

5. *Crude or Partially Settled Sewage upon Percolating Filters.*—Broadly speaking, the volume of such sewage which can be treated upon percolating filters, with the production of a good effluent, depends mainly upon its strength, especially if no complications ensue through the choking of the filter and if the latter is working up to its full power. Twenty to 25 gallons per cube yard per day of a sewage whose strength is about 170, or 60 gallons of sewage with a strength of 60, can be successfully dealt with upon filters of medium to coarse material, 2,500 to 3,500 units of purification being obtained (p. 16). When the sewage is *well settled*, about 100 to 120 gallons of such sewage with a strength of about 80 can be filtered per cube yard per day, and 7,000 to 8,000 units of purification, or probably even more than this,‡ obtained. In this case, therefore, the process is comparable with the treatment of septic tank liquor upon percolating filters.

6. *Septic Tank Liquor upon Single Contact Beds.*—The volume of septic tank liquor which can be treated by single contact probably varies inversely as the strength of the liquor, but the data in this case are inconclusive (p. 17). Primary beds of medium to coarse or medium to fine material, 4 to 5 feet deep, may be expected to give from 3,000 to 4,500 units of purification, when dealing with either strong or weak liquors. If the tank liquor is a weak one, and if the material of the bed is fine, this purification will be sufficient to yield a good or fairly good effluent, but not otherwise. A weak liquor, of strength 30 to 50, and containing up to 6 or 8 parts of suspended solids, can in this way be successfully treated at the rate of 100 to 150 gallons per cube yard per day. As a rule, however, septic tank liquors are too strong to allow of one contact being sufficient to give a good effluent (p. 18).

7. *Septic Tank Liquor upon Double Contact Beds.*—The volume of septic tank liquor which can be successfully treated by double contact depends mainly upon its strength, but the less suspended and colloidal solids the liquor contains, the longer will the beds retain their capacity. Upon primary beds of medium to fine material, 3 or 4 feet deep, a strong liquor of strength 90 may be treated at the rate of 50 gallons per cube yard per day; a liquor of strength 70 at the rate of 70 gallons; and a weak liquor of strength 40 at the rate of 100 gallons. From 3,500 to 4,500 units of purification may be expected here, with the production of good effluents (p. 20). The Accrington experiments go to show that double contact beds will, during their first year of work, at the rate of two fillings per day,

* Instead of using gallons per cube yard as the multiplicator, litres per cubic metre may be taken.

† For a modification of this statement, *cf.* the second addendum to this paper, pp. 50–51.

‡ *Cf.* Report to the Commission on the Dorking Experimental Installation, Part I, by E. H. Richards (this Appendix).

treat 75 gallons of strong or 150 gallons of weak liquor and will give 5,000 to 6,000 units of purification for the first year. Their aggregate working power will, however, gradually fall off as the beds lose capacity (p. 20).

8. *Septic Tank Liquor upon Percolating Filters.*—The volume of septic tank liquor which can be treated upon percolating filters varies more or less inversely as the strength. A percolating filter of coarse or of medium to coarse material, and from 6 to 9 feet in depth, may be expected to give from 7,000 to 11,000 units of purification when treating either strong or weak tank liquors, and to yield good effluents. This would correspond to 80 gallons per cube yard of a strong liquor of strength 113, or 150 gallons of a slightly weak liquor of strength 58. The less coarse the material, provided that it can allow the free passage of effluent suspended solids through it, the greater is the relative purification per cube yard (p. 22). The Accrington Experiments I., II., and III. go to show that percolating filters of coarse material, 6 feet deep, can treat a strong septic tank liquor (strength = 73 to 85) at a rate of 100 to 125 gallons per cube yard per day, or a liquor of half this strength at a rate of 200 to 250 gallons, can give from 8,000 to 9,000 units of purification, and can produce at the same time a good effluent.*

9. *Precipitation Liquor upon Single Contact Beds.*—Our data with regard to this process are rather few, but they indicate clearly that—as in the case of settled sewage and septic tank liquor—single contact of precipitation liquor from strong sewages is not sufficient to produce a good effluent. The better clarified the liquor is, the more of it can be treated. The very well-clarified liquor at Kingston-on-Thames, with a strength of about 50, was treated for over six years upon an experimental coke bed of medium to coarse material, 3 feet deep, at a rate of 250 gallons per cube yard per day (four fillings), giving 10,800 units of purification and producing a fair to good effluent. A more dilute tank liquor, equally well clarified, might be treated in even larger volume than this, so far as the "strength" was concerned, but it is doubtful whether more than four fillings per day would be practicable on a large scale for any length of time (pp. 23–24).

10. *Precipitation Liquor upon Double Contact Beds.*—We have had no actual experience of this process, which would be applicable to precipitation liquors from strong sewages. We should not expect, however, to obtain such a high figure for units of purification as in the treatment of medium or weak liquor by single contact. Probably about 6,000 to 7,000 units would be the maximum obtainable. This would correspond to about two to two and a half fillings per day of a liquor of strength 100, or about three to three and a half fillings of a liquor of strength 75.

11. *Precipitation Liquor upon Percolating Filters.*—In this case it cannot be said that the volume of precipitation liquor treated per cube yard of filter at the different places under observation varied inversely as the strength. The main reason for this is that suspended solids can be reduced in most precipitation liquors to a very low figure, in which case very fine material may be used for the filtration of large volumes. At the places which were under observation the filtering material varied greatly in size and the liquors contained very different quantities of suspended solids. With material of a given size, the curves representing strength and volume would no doubt bear an inverse relation to one another. From the results obtained with percolating filters, of coarse and fine material respectively, we have, however, arrived at the following broad conclusions :—

(*a*) The volume of precipitation liquor which can be treated upon filters of *coarse* material depends mainly upon the strength of the liquor.

(*b*) The volume which can be treated upon filters of *fine* material depends not merely upon the strength but also to a marked extent upon the degree of clarification of the liquor (p. 26).

Upon deep filters of coarse material, about 150 gallons of precipitation liquor of about average strength (strength 50 to 60) or 200 to 250 gallons of weak liquor (strength 30 to 40) can be treated per cube yard per day, yielding up to about 8,000 units of purification, and producing a good effluent. In the case of very strong liquors the volume would probably have to be *more than* proportionately reduced (p. 26).

Upon shallow filters of fine material, a *clear* liquor with a strength of 50 can be treated at the rate of 300 to 400 gallons per cube yard per day, giving about 18,000 units of purification, and producing a very fair to good effluent. It has to be borne in mind,

* Experiment IV. showed that, under favourable conditions of summer weather, even larger volumes than these can be treated (this Appendix, p. 71).

however, that filters of very fine material working at this rate have to be constantly washed and scraped. About 500 gallons per cube yard per day would probably be the largest volume of any liquor, however weak, that could be coped with practically on such filters (p. 26).

The following table gives an *approximate* idea of the relative purification which can be effected by different kinds of filter treating different liquors, so as to produce a fair to good effluent :—

	Units of Purification :—	
	On the basis of gallons per cube yard.	On the basis of litres per cubic metre.
Crude or partially settled sewage upon double contact beds - - - - - -	3,000 to 4,000	18,000 to 24,000
Crude or partially settled sewage upon percolating filters - - - - - - -	2,500 to 3,500	15,000 to 21,000
Well-settled sewage upon percolating filters -	7,000 to 8,000, and probably up to 11,000	42,000 to 48,000, and probably up to 65,000
Septic tank liquor upon single contact beds - -	3,000 to 4,500	18,000 to 27,000
Septic tank liquor upon double contact beds -	3,500 to 4,500	21,000 to 27,000
Septic tank liquor upon percolating filters - -	7,000 to 11,000	42,000 to 65,000
Precipitation liquor upon single contact beds -	Up to 11,000	Up to 65,000
Precipitation liquor upon double contact beds -	*Probably* up to 6,000 to 7,000	*Probably* up to 36,000 to 42,000.
Precipitation liquor upon :—		
(*a*) Percolating filters of coarse material -	Up to about 8,000	Up to about 48,000
(*b*) Percolating filters of fine material -	Up to about 18,000	Up to about 107,000

TABLE II.*

A.	B.	C.				D.			E.
		Filter Effluent; Figures of Analysis.				Strength or Oxidizability of Filter Effluent :—			
						(a)	(b)	(c)	
Nature of liquor treated.	† Calculated strength of liquor treated.	Ammoniacal + Organic Nitrogen.	Volatile Solids.	"Oxygen absorbed" from $\frac{N}{8}$ Permanganate in 4 hours.	Nitric Nitrogen.	Whole Effluent, including Suspended Solids.	Effluent without Suspended Solids.	Effluent without Suspended Solids and Nitrate.	Oxygen used up producin this Effluent (B—D)
ACCRINGTON, EXPERIMENT I.—Septic Liquor and Percolation.									
Strong Liquor -	85·2	1·79	5·4	3·39	2·26	12·1	1·7	8·5	73·1
Weak Liquor -	48·0	1·43	3·9	2·28	1·53	9·6	1·8	6·4	38·4
Septic Liquor and Single Contact.									
Strong Liquor -	85·7	3·64	5·0	4·64	0·06	35·5	25·5	25·7	50·2
Weak Liquor -	42·0	1·54	3·1	2·19	0·10	17·2	11·1	11·4	24·8
Septic Liquor and Double Contact.									
Strong Liquor -	85·7	2·24	4·1	3·13	0·66	16·3	8·1	10·1	69·4
Weak Liquor -	42 0	0 86	say 1·0	1·42	0·63	4·0	2·0	3·9	38·0
ACCRINGTON, EXPERIMENT II.—Septic Liquor and Percolation.									
Strong Liquor -	81·2	0·79	1·5	1·54	3·25	‡ −3·2	−6·2	3·6	84·4
Weak Liquor -	40·5	0·53	1·3	0·99	1·89	−0·7	−3·3	5·0	41·2
Septic Liquor and Single Contact.									
Strong Liquor -	83·3	3·24	6·2	4·28	0·05	35·4	23·2	23·4	47·9
Weak Liquor -	42·2	1·56	2·7	2·14	0·20	16·1	10·7	11·3	26·1
Septic Liquor and Double Contact.									
Strong Liquor -	83·3	1·85	4·1	2·86	0·64 (+0·33 Nitrous Nitrogen).	14·0	5·8	8·1	69·3
Weak Liquor -	42·2	0·70	2·0	1·23	1·00	4·2	0·2	3·2	38·0
ACCRINGTON, EXPERIMENT III.—Septic Liquor and Percolation.									
Strong Liquor (A)	73·2	1·07	5·5	3·61	2·32	8·8	−2·2	4·8	64 4
Weak Liquor (B)	40·7	0·59	2·6	1·94	1·36	3·8	−1·4	2·7	36·9

* This table is explained, so far as is necessary, on pp. 12–13.
† *Note.*—The figures in columns B, C, D, and E, in all the sheets of Table II., represent parts per 100,000
‡ The minus sign indicates that the oxygen present in the form of nitrate was, to the extent of the figure agains

TABLE II.

F.	G.	G 1. Percentage Purification :—				H.	I.	
llons of iquor ited per be yard filter r day nstant low).	Units of Purification per cube yard of filter (*cf.* "units" of purification, p. 27).	(a) On Atmospheric Oxygen taken up in the process.	(b) On Atmospheric Oxygen taken up, leaving out of account the Suspended Solids of the Effluent.	(c) On Atmospheric Oxygen taken up, leaving out of account the Suspended Solids and Nitrate of the Effluent.	(d) On "Oxygen absorbed" from Permanganate in 4 hours (including the Suspended Solids of the Effluent).	General quality of Effluent (considered from the standpoint of a final Effluent).	Size of material in filter.	Depth of filter (feet).
100	7,310	86	98	90	62	Good, apart from solids.	Coarse.	6 ft.
200	7,680	80	96	87	55	Good, apart from solids.	Coarse.	6 ft.
144·4	7,249	59	70	70	48	Bad.	Medium to coarse.	3 ft.
297·6	7,380	59	74	73	51	Bad.	Medium to coarse.	3 ft.
72·2	5,011	81	91	88	65	Fair, apart from solids.	Secondary, fine.	3 ft.
148·8	5,654	90	95	91	68	Good.	Secondary, fine.	3 ft.
100	8,440	104	108	96	81	Very good.	Coarse.	6 ft.
100	4,120	102	108	88	76	Very good.	Coarse.	6 ft.
103·2	4,944	58	72	72	50	Bad.	Medium to coarse.	3 ft.
115·8	3,024	62	75	73	50	Poor.	Medium to coarse.	3 ft.
51·6	3,576	83	93	90	66	Very fair, apart from solids.	Secondary, fine.	3 ft.
57·9	2,200	90	100	92	71	Good, apart from solids.	Secondary, fine.	3 ft.
125	8,050	88	103	93	57	Good, apart from solids.	Coarse.	6 ft.
250	9,225	91	103	93	59	Good, apart from solids, but not so good as (A).	Coarse.	6 ft.

age liquor or effluent.
ch it is placed, more than sufficient to oxidize the ammonia and organic matter in the effluent.

TABLE II.—*continued.*

A.	B.	C.				D.			E.
		Filter Effluent ; Figures of Analysis.				Strength of Oxidizability of Filter Effluent :—			
						(a)	(b)	(c)	
Nature of liquor treated.	Calculated strength of liquor treated.	Ammoniacal + Organic Nitrogen.	Volatile Solids.	"Oxygen absorbed" from Permanganate in 4 hours.	Nitric Nitrogen.	Whole Effluent, including Suspended Solids.	Effluent without Suspended Solids.	Effluent without Suspended Solids and Nitrate.	Oxyg used u produc this Efflue (B—D
DORKING EXPERIMENTS.									
SETTLED SEWAGE AND PERCOLATION.									
November, 1905 to November, 1906.	80·1	2·19	3·88	2·93	2·6	8·8	1·0	8·8	71·
SEPTIC LIQUOR AND PERCOLATION.									
November, 1905 to November, 1906.	81·6	2·34	4·67	3·60	2·9	11·2	1·8	10·5	70·
PRECIPITATION LIQUOR AND PERCOLATION.									
Experiment I.									
10 grains Alumino-ferric. February 6th to July 2nd, 1906.	68·8	3·17	4·77	2·61	1·9	18·1	8·6	14·3	50·
Experiment II.									
5 grains Lime+10 grains Alumino-ferric. July 11th to August 20th, 1906.	53·5	1·38	2·98	1·80	2·9	3·5	– 2·5	6·2	51·
Experiment III.									
5 grains Lime+10 grains Alumino-ferric. August 29th to November 10th, 1906.	55·3	1·41	3·14	1·75	2·9	3·9	– 2·6	6·3	51·

TABLE II.—*continued.*

F.	G.	G 1.				H.	I.	J.
		Percentage Purification:—						
(G)allons of liquor (tr)eated per (cu)be yard (o)f filter (p)er day (c)onstant flow).	Units of Purification per cube yard of filter.	(a) On Atmospheric Oxygen taken up in the process.	(b) On Atmospheric Oxygen taken up, leaving out of account the Suspended Solids of the Effluent.	(c) On Atmospheric Oxygen taken up, leaving out of account the Suspended Solids and Nitrate of the Effluent.	(d) On "Oxygen absorbed" from Permanganate in 4 hours (including the Suspended Solids of the Effluent).	General quality of Effluent (considered from the standpoint of a final Effluent).	Size of material in filter.	Depth of filter (feet).
120	8,556	89	99	89	62	Fair. Filter was maturing throughout this experiment.	Coarse	6 feet.
120	8,448	86	98	87	53	Moderate. Filter was maturing throughout this experiment.	Coarse	6 feet.
120	6,084	74	88	79	62	Not very good. This purification was affected by growths. Filter not really quite matured during this experiment.	Coarse	6 feet.
175	9,065	93	105	89	62	Very fair or fair.	Coarse	6 feet.
211	10,845	93	105	90	62	Very fair or fair.	Coarse	6 feet.

TABLE II.—*continued.*

A. Place.	B. Calculated strength of liquor treated.	C. Filter Effluent; Figures of analysis:— Ammoniacal + Organic Nitrogen.	Volatile Solids.	"Oxygen absorbed" from Permanganate in 4 hours.	Nitric Nitrogen.	D. Strength or Oxidizability of Filter Effluent:— (a) Whole Effluent, including Suspended Solids.	(b) Effluent without Suspended Solids.	(c) Effluent without Suspended Solids and Nitrate.	E. Oxygen used up in producing this Effluent (B – D)
SEWAGE AND SINGLE CONTACT.									
Oldham - - (Settled.) 1903–4.	51·1	2·0	say, 3·8	0·99	0·31	15·7	8·1	9·0	35·4
SEWAGE AND DOUBLE CONTACT.									
Withnell - - (Crude.) July, 1904.	174	1·7 ap.	4·9	3·86	0·0	25·3	14·5	14·5	148·7
*Maidstone - (Crude.) September, 1903.	164	1·36	1·0 ap.	2·52	1·13	4·7	2·7	6·1	159·3
Leeds - - - (Crude.) February and March, 1899.	127	0·62	1·7 ap.	0·75	0·35	5·2	1·8	2·9	121·8
†Oswestry - - (Settled.) February, 1903.	91	1·14	1·4 ap.	1·76	1·06	4·7	2·0	5·1	86·3
‡Halton - - (Settled.) July, 1903.	80	2·0 ap.	2·0 ap.	2·52	0·72 ap.	10·8	6·8	9·0	69·2
Sheffield - - (Settled.) 1903–4.	57·6	0·46	1·2 ap.	0·60	1·6	5·1	2·7	7·5	52·5
SEWAGE AND TRIPLE CONTACT.									
§Hampton - - (Crude.) June, 1902.	172	0·93	Tr.	1·31	2·62	– 3·7	– 3·7	4·2	175·7
SEWAGE AND PERCOLATION.									
Leeds (Ducat) (Crude.) June, 1900.	172·6	0·29	(?)	0·34 (weak)	1·20	– 2·3		1·3	174·9
Little Drayton (B) (Settled.) April, 1905.	165	1·74	4·5 ap.	2·92	3·48	6·4	– 2·6	7·8	158·6
Leeds Filter - (Crude.) Dec., 1903.	123	1·26	? 16·0	3·09 (weak)	0·35	36·7	4·7 [?]	5·8	86·3
Clifton (Settled) - January, 1904.	123	1·06	1·6	1·10	0·80	5·8	2·6	5·0	117·2
Hendon (Ducat) - (Crude.) September, 1903.	107	1·92 ap.	3·0	2·65	2·23	7·9	1·9	8·6	99·1
Dorking Experimental (Settled.) Nov., 1905, to Nov., 1906.	80·1	2·19	3·88	2·93	2·6	8·8	1·2	9·0	71·3
Leeds (Settled) - 1904.	59·7	0·57	say, 9·0	1·71 (weak)	1·24	16·9	– 1·3	2·4	42·8

* *Maidstone.*—3 Hourly sets of crude sewage and 9 chance samples of effluent.
† *Oswestry.*—4 Hourly sets of settled sewage and 10 chance samples of effluent.

TABLE II.—*continued.*

F.	G.	G 1. Percentage Purification :—				H.	I.	J.
...lons of ...quor ...ted per ...e yard ...filter ...r day ...dry- ...ather ...w or ...stant ...ow).	Units of Purification per cube yard of filter.	(a) On Atmospheric Oxygen taken up in the process.	(b) On Atmospheric Oxygen taken up, leaving out of account the Suspended Solids of the Effluent.	(c) On Atmospheric Oxygen taken up, leaving out of account the Suspended Solids and Nitrate of the Effluent.	(d) On "Oxygen absorbed" from Permanganate in 4 hours (including the Suspended Solids of the Effluent).	General quality of Effluent (considered from the standpoint of a final Effluent).	Size of Material in filter.	Depth of filter (feet).
73 ...erage ...ntity).	2,584	69	84	82	68	Moderate.	Medium to fine.	1 ft. 6 in. to 3 ft.
·2	2,706	86	92	92	82	Not satisfactory.	Primary, coarse. Secondary, medium.	5 ft. 3 ft. 6 in.
·7	3,775	97	98	96	88	Moderate or fair.	Primary, coarse. Secondary, fine.	3 ft. 4 in. 4 ft. 4 in
32	3,998	96	99	98	93	Moderate.	Primary, coarse. Secondary, medium.	5 ft. 6 ft.
41	3,538	95	98	94	83	Fair.	Primary, medium to coarse. Secondary, medium.	4 ft. 6 in. 4 ft. 6 in.
...W.F.) ...actual ...ntity)	3,737 7,335	87	92	89	70	Indifferent.	Primary, coarse. Secondary, coarse.	4 ft. 3 in. 3 ft. 3 in.
60	3,150	91	95	87	86	Good.	Primary and Secondary, medium to fine.	3 ft.
43	7,555	102	102	98	92	Good or very good.	Primary, coarse. Secondary, medium. Tertiary, fine.	4 ft. 4 ft. 4 ft.
25	4,373	101	over 101	99	98	Very good.	Medium.	10 ft.
.5·2	2,411	96	102	95	84	Good to fair.	Medium.	7 ft. 6 in.
52	4,488	70	96	95	70	Fair.	Very coarse.	11 ft. 6 in.
.5·6	1,828	95	98	96	93	Good to fair.	Very fine to coarse.	4 ft.
·0	3,964	93	98	92	77	Good, when settled.	Medium.	8 ft. and 10 ft.
20	8,556	88	99	89	62	Fair.	Coarse.	6 ft.
33	2,696	72	102	96	71	Good, apart from solids.	Coarse.	9 ft. 6 in.

‡ *Halton.*—3 Hourly sets of crude sewage and 5 chance samples of effluent.
§ *Hampton.*—3 Hourly sets of crude sewage and 12 chance samples of effluent.

TABLE II.—*continued.*

A.	B.	C.				D.			E.
		Filter Effluent; Figures of Analysis.				Strength or Oxidizability of Filter Effluent:—			
						(a)	(b)	(c)	
Place.	Calculated strength of liquor treated.	Ammoniacal + Organic Nitrogen.	Volatile Solids.	"Oxygen absorbed" from Permanganate in 4 hours.	Nitric Nitrogen.	Whole Effluent, including Suspended Solids.	Effluent without Suspended Solids.	Effluent without Suspended Solids and Nitrate.	Oxygen used up i producin this Effluent (B – D).
SEPTIC LIQUOR AND SINGLE CONTACT.									
Hartley Wintney (A) January, 1904.	108	1·76	2·4	3·14	1·4 ap.	8·5	3·7	7·9	99·5
*Hartley Wintney (A) January, 1904.	108	4·3	5·4	3·26	0·95	27·3	16·9	19·8	80·7
Manchester - - April, 1903 to December, 1904.	106	1·93	say, 3·6	2·73	0·31	(a) 15·0 (b) 23·8	(a) 7·8 (b) 16·6	(a) 8·7 (b) 17·5	(a) 91·0 (b) 82·2
Exeter (Main Works) June, 1903.	99	4·0 ap.	3·2	3·67	0·21	31·2	24·8	25·4	67·8
Andover - - October, 1904.	90	5·87	7·3	4·3	0·0	50·5	35·9	35·9	39·5
Accrington - - Experiment I. Strong Liquor.	85·7	3·64	5·0	4·64	0·06	35·5	25·5	25·7	50·2
Accrington - - Experiment I. Weak Liquor.	43·0	1·54	3·1	2·19	0·1	17·2	11·1	11·4	25·8
Accrington - - Experiment II. Strong Liquor.	83·3	3·24	6·2	4·28	0·05	35·4	23·2	23·4	47·9
Accrington - - Experiment II. Weak Liquor.	42·2	1·56	2·7	2·14	0·2	16·1	10·7	11·3	26·1
Exeter (Old Works) (B) June to July, 1903.	39	1·4 ap.	0·7	0·85	1·46	3·0	1·6	6·0	36·0
†Slaithwaite - June, 1902.	35·6 Hourly. 35·2 Chance.	1·29	1·0 ap.	2·15	0·52	6·3	4·3	5·9	29 3

* *Hartley Wintney.*—3 Hourly sets of tank liquor compared with 7 chance samples of effluent.
† *Slaithwaite.*—3 Hourly sets of tank liquor compared with 7 chance samples of effluent.

TABLE II.—*continued.*

F. Gallons of liquor treated per cube yard of filter per day (dry-weather flow or constant flow).	G. Units of Purification per cube yard of filter.	G 1. Percentage Purification :— (a) On Atmospheric Oxygen taken up in the process.	(b) On Atmospheric Oxygen taken up, leaving out of account the Suspended Solids of the Effluent.	(c) On Atmospheric Oxygen taken up, leaving out of account the Suspended Solids and Nitrate of the Effluent.	(d) On "Oxygen absorbed" from Permanganate in 4 hours (including the Suspended Solids of the Effluent).	H. General quality of Effluent (considered from the standpoint of a final Effluent).	I. Size of Material in filter.	J. Depth of filter (feet).
73	7,264	92	97	93	76	Moderate.	Medium to fine.	4 ft.
73 (?)	5,871	75	76	82	75	Poor.	Medium to fine.	4 ft.
77 (average quantity).	(a) 7,007 (b) 6,329	(a) 86 (b) 78	(a) 93 (b) 84	(a) 92 (b) 83	68	Rather poor.	Medium.	3 ft. 4 in.
55	3,729	68	65	64	64	Poor.	Medium to coarse.	4 ft. 6 in.
115	4,543	44	60	60	43	Poor.	Medium to fine.	4 ft.
144·4	7,248	59	70	70	48	Bad.	Medium to coarse.	3 ft.
297·6	7,380	69	74	74	51	Bad.	Medium to coarse.	3 ft.
103·2	4,944	58	72	72	50	Bad.	Medium to coarse.	3 ft.
115·8	3,022	62	73	73	50	Poor.	Medium to coarse.	3 ft.
75 ap.	2,700	92	96	85	75	Fair.	Medium to fine.	5 ft.
62	1,817	82	91	83	44	Indifferent.	Medium to coarse	5 ft.

TABLE II.—*continued.*

A. Place.	B. Calculated strength of liquor treated.	C. Filter Effluent; Figures of Analysis. Ammoniacal + *Organic Nitrogen.	Volatile Solids.	"Oxygen absorbed" from Permanganate in 4 hours.	Nitric Nitrogen.	D. Strength or Oxidizability of Filter Effluent:— (a) Whole Effluent, including Suspended Solids.	(b) Effluent without Suspended Solids.	(c) Effluent without Suspended Solids and Nitrate.	E. Oxygen used up in producing this Effluent (B—D).
SEPTIC LIQUOR AND DOUBLE CONTACT.									
*Guildford - - July, 1902, and November, 1904.	125	1·7 ap.	1·0 ap.	2·77	1·17	6·2	4·2	7·7	118·8
Leeds - - 1901 to 1904.	92·4	0·38	0·2	0·51 (weak.)	1·75	–3·1	–3·5	1·8	95·5
Huddersfield - 1900 to 1904.	77·1	0·48	1·2 ap.	1·53 (weak.)	0·49	3·1	0·7	2·2	74·0
Burnley - - 1903.	74·1	0·36	say, 0·2	0·78 (weak.)	1·0	–1·0	–1·4	1·6	75·1
Accrington - - Experiment I. Strong Liquor.	85·7	2·24	4·1	3·13	0·66	16·3	8·1	10·1	69·4
Accrington - - Experiment I. Weak liquor.	43·0	0·86	say, 1·0	1·42	0·63	4·0	2·0	3·9	39·0
Accrington - - Experiment II. Strong liquor.	83·3	1·85	4·1	2·86	0·64 (+0·33 Nitrous Nitrogen)	14·0	5·8	7·7	69·3
Accrington - - Experiment II. Weak liquor.	42·2	0·70	2·0	1·23	1·0	4·2	0·2	3·2	38·0

* *Guildford.*—Five Hourly sets of tank liquor compared with seven

TABLE II.—*continued.*

F. Gallons of liquor treated per cube yard of filter per day (dry-weather flow or constant flow).	G. Units of Purification per cube yard of filter.	G 1. Percentage Purification:— (a) On Atmospheric Oxygen taken up in the process.	(b) On Atmospheric Oxygen taken up, leaving out of account the Suspended Solids of the Effluent.	(c) On Atmospheric Oxygen taken up, leaving out of account the Suspended Solids and Nitrate of the Effluent.	(d) On "Oxygen absorbed" from Permanganate in 4 hours (including the Suspended Solids of the Effluent)	H. General quality of Effluent (considered from the standpoint of a final Effluent).	I. Size of Material in filter.	J. Depth of filter (feet).
22·7	2,697	95	97	94	76	Moderate.	Primary, medium to coarse. Secondary, medium to fine.	2 ft. 6 in. 2 ft. 6 in.
45	4,298	103	104	98	93	Good.	Primary, fine to medium. Secondary, medium.	5 ft. 6 ft.
76	5,624	96	99	97	75	Fair to good.	Primary, coarse. Secondary, medium.	3 ft. 9 in. 2ft. 11in.
40	3,004 (or 3,312 at strength of 81·8)	101	102	98	88	Good.	Primary, coarse. Secondary, fine.	3 ft. 3 ft.
72·2	5,011	81	91	88	65	Fair, apart from solids.	Primary, medium to coarse. Secondary, fine.	3 ft. 3 ft.
148·8	5,654	91	95	91	68	Good.	Primary, medium to coarse. Secondary, fine.	3 ft. 3 ft.
51·6	3,576	83	93	91	66	Very fair, apart from solids.	Primary, medium to coarse. Secondary, fine.	3 ft. 3 ft.
57·9	2,200	90	100	92	71	Good, apart from solids.	Primary, medium to coarse. Secondary, fine.	3 ft. 3 ft.

chance samples of effluent; this is not a good comparison.

TABLE II.—*continued.*

A.	B.	C.				D.			E.
		Filter Effluent ; Figures of Analysis.				Strength or Oxidizability of Filter Effluent :—			
						(a)	(b)	(c)	
Place.	Calculated strength of Liquor treated.	Ammoniacal + Organic Nitrogen.	Volatile Solids.	"Oxygen absorbed" from Permanganate in 4 hours.	Nitric Nitrogen.	Whole Effluent, including Suspended Solids.	Effluent without Suspended Solids.	Effluent without Suspended Solids and Nitrate.	Oxygen used up in producing this Effluent (B—D).
SEPTIC LIQUOR AND PERCOLATION.									
Caterham - - April, 1902.	161	7·6	2·8 ap	5·22	8·2 (+ 0·7 nitrous nitrogen).	14·0	8·4	34·3	147
Birmingham - 1906.	113	3·44	say, 5·5	2·58 (weak)	2·1	20·2	9·2	15·5	92·8
Guildford - - (4 samples). May to July, 1907.	109·2	1·0	6·9	3·37	4·5	4·8	– 9 0	4·5	104·4
*Guildford - - May to July, 1907.	90·3	1·0	6·9	—	4·5	4·8	– 9·0	4·5	85·5
Accrington - - May to September, 1901.	94	3·18	10·3	5·08	2·16	28·4	7·8	14·3	65·6
Accrington - - Experiment I. Strong liquor.	85·2	1·79	5·4	3·39	2·26	12 1	1·7	8·5	73·1
Rochdale - - May, 1904.	83	0·97	3·3	1·68	2·15	4·4	– 2·2	4·3	78·9
Dorking - - (Experimental.) November, 1905, to November, 1906.	81·6	2·34	4·67	3·60	2·9	11·2	1·9	10·6	70·4
Accrington - - Experiment II. Strong liquor.	81·2	0·79	1·5	1·54	3·25	– 3·2	– 6·2	3·6	84·4
Huddersfield - 1903–4.	77·1	0·41	8·8	1·29 † (weak)	1·0	16·4	– 1·0	2·0	62·7
Leeds - - - 1900–1903.	75·8	0·79	(?) 3·4	1·60 (weak)	1·08	7·2	– 0·4	3·6	68·6
Accrington - - Experiment III. Strong liquor.	73·2	1·07	5·5	3·61	2·32	8·8	– 2·2	4·8	64·4
York - - - November, 1903.	58	0·30	0·93	1·17	2·22	– 3·5	– 5·4	1·3	61·5
Accrington - - Experiment I. Weak liquor.	48·0	1·43	3·9	2·28	1·53	9·6	2·0	6·6	38·4
Accrington - - Experiment III. Weak liquor.	40·7	0·59	2·6	1·94	1·36	3·8	– 1·4	2·7	36·9
Accrington - - Experiment II. Weak liquor.	40·5	0·53	1·3	0·99	1·89	– 0·7	– 3·3	2·4	41·2
Prestolee - - November, 1903.	22	0·23	0·0	0·31	0·33	0	0	1·0	22·0

* *Guildford.*—Allowing in the second case the normal ratio between the "*oxygen absorbed*" *at once* and *in four hours* by the tank liquor, *i.e.*, 1 : 3·5. This second calculation is to be taken in preference to the first.

TABLE II.—*continued.*

F.	G.	G 1.				H.	I.	J.
		Percentage Purification :—						
		(a)	(b)	(c)	(d)			
Gallons of liquor treated per cube yard of filter per day (dry-weather flow or constant flow).	Units of Purification per cube yard of filter.	On Atmospheric Oxygen taken up in the process.	On Atmospheric Oxygen taken up, leaving out of account the Suspended Solids of the Effluent.	On Atmospheric Oxygen taken up, leaving out of account the Suspended Solids and Nitrate of the Effluent.	On "Oxygen absorbed" from Permanganate in 4 hours (including the Suspended Solids of the Effluent)	General quality of Effluent (considered from the standpoint of a final Effluent).	Size of material in filter.	Depth of filter. (feet).
31	4,557	91	95	79	49	Fair.	Medium to coarse.	5 ft.
82·5	7,656	82	92	86	78	Fair to good.	Medium to coarse.	6 ft. to 7 ft.
50	5,220	96	108	96	78	Good.	Coarse.	6 ft.
50	4,275	95	110	95	—	Good.	Coarse.	6 ft.
140	9,184	70	92	85	45	Good to fair (apart from solids).	Coarse.	7 ft. to 9 ft.
100	7,310	86	98	90	62	Good (apart from solids).	Coarse.	6 ft.
141	11,125	95	103	95	84 (settled effluent)	Good.	Coarse.	9 ft.
120	8,448	86	98	86	53	Moderate.	Coarse.	6 ft.
100	8,440	104	108	96	81	Very good.	Coarse.	6 ft.
110	6,897	81	101	97	79 (settled effluent)	Good (apart from solids).	Coarse.	7 ft.
63	4,322	90	101	95	74	Good (apart from solids).	Coarse.	9 ft. 6 in.
125	8,050	88	103	93	57	Good (apart from solids).	Coarse.	6 ft.
150	9,225	106	109	98	84	Very good.	Coarse.	6 ft. 6 in. and 7 ft. 8 in.
200	7,680	80	96	86	55	Good (apart from solids).	Coarse.	6 ft.
250	9,225	91	103	93	59	Good (apart from solids).	Coarse.	6 ft.
100	4,120	102	108	94	76	Very good.	Coarse.	6 ft.
46	1,012	100	100	95	89	Exceptionally good.	Fine to coarse.	5 ft.

† At Huddersfield the filter effluents are settled before being analysed.

TABLE II.—*continued.*

A	B.	C.				D.			E.
		Filter Effluent ; Figures of Analysis.				Strength or Oxidizability of Filter Effluent :—			
						(a)	(b)	(c)	
Place.	Calculated strength of Liquor treated.	Ammon-iacal + Organic Nitrogen.	Volatile Solids.	"Oxygen absorbed" from Per-manganate in 4 hours.	Nitric Nitrogen.	Whole Effluent, including Suspended Solids.	Effluent without Suspended Solids.	Effluent without Suspended Solids and Nitrate.	Oxygen used up producing this Effluent (B—D)
PRECIPITATION LIQUOR AND SINGLE CONTACT.									
*Calverley (B.) - July, 1904.	124	3·35	6·0 ap.	3·57	0·33	33·2	21·2	22·2	90·8
Kingston - - (Experimental). July, 1903.	51	2·16 ap	0·8 ap.	0·84	1·21	7·7	6·1	9·7	43·3
‡Heywood - - (1903).	40·2	2·26	say, 1·0 §	0·96 (weak)	0·40	11·0	9·0	10·2	29·2
PRECIPITATION LIQUOR AND PERCOLATION.									
Normanton (B) - March, 1904.	92	3·09	Tr.	1·86	1·30	10·0	10·0	13·9	82·0
‖ Withnell (A) - July, 1904.	81	3·2	Tr.	1·92	1·65	9·3	9·3	15·3	71·7
¶ Withnell (X) - 1903–1905.	29·8	0·31	Say, 0 5	1·10	0·75	0	– 1·0	1·3	29·8
Dorking - - (Experimental) I. 10 grains Al. Ferric per gallon. February 6th to July 2nd, 1906.	68·8	3·17	4·77	2·61	1·9	18·1	8·6	14·3	50·7
Dorking - - (Experimental) II. 5 grains Lime, + 10 grains Al. Ferric. July 11th to Aug. 20th, 1906.	53·5	1·38	2·98	1·80	2·9	3·5	– 2·5	6·2	51·8
Dorking - - (Experimental) III. 5 grains Lime, + 10 grains Al. Ferric. Aug. 29th to Nov. 10th, 1906.	55·3	1·41	3·14	1·75	2·9	3·9	– 2·6	6·3	51·4
Leeds - - July, 1904, to March, 1905.	51·8	0·48	1·2	0·67 (weak)	1·66	– 0·4	– 2·8	2·2	52·2
** Chorley - - July and Aug., 1903	50	1·43	0·4 ap.	1·14	2·17	0·9	0·1	6·6	49·1
†† Rochdale - September, 1906, to July, 1907.	39	0·73	4·4	1·94	2·14	5·7	– 3·1	3·3	33·3
Horfield - - May, 1903.	36	2·0	1·56	1·60	2·0 ap.	6·0	2·9	8·9	30·0

* *Calverley.*—Three hourly sets of precipitation liquor compared with 13 chance samples of effluent.

† This is an estimate, based on the water supply.

‡ From our general knowledge of the Heywood precipitation liquor, we think that it is really stronger than t[he] above figure indicates, since it is derived from a fairly strong sewage.

§ This is an estimate.

‖ *Withnell "A."*—This refers to only one hourly set of precipitation liquor and one of effluent.

¶ *Withnell "X."*—Comparison of four chance samples of precipitation liquor, Nos. 489, 3,425A, 3,597, and 3,65[8] with four chance Effluents from Filters A and B, Nos. 490, 3,426B, 3,598, and 3,659. This comparison is of little or no valu[e]

TABLE II.—*continued.*

F.	G.	G 1.				H.	I.	J.
		Percentage Purification :—						
		(a)	(b)	(c)	(d)			
Gallons of liquor treated per cube yard of filter per day (dry-weather flow or constant flow).	Units of Purification per cube yard of filter.	On Atmospheric Oxygen taken up in the process.	On Atmospheric Oxygen taken up, leaving out of account the Suspended Solids of tho Effluent.	On Atmospheric Oxygen taken up, leaving out of account the Suspended Solids and Nitrate of the Effluent.	On "Oxygen absorbed" from Permanganate in 4 hours (including the Suspended Solids of theEffluent)	General quality of Effluent (considered from the standpoint of a final Effluent).	Size of material in filter.	Depth of filter (feet).
60 (?) †	5,448 (?) †	73	82	82	70	Poor.	Coarse to fine.	3 feet.
250	10,825	85	88	81	84	Good, or fair to good.	Medium to coarse.	3 feet.
173	5,052	73	78	75	72	Evidently not very good.	Very fine to coarse.	4 feet 3 inches.
98	8,036	89	89	85	82	Very fair.	Very fine to coarse.	3 ft. 3 in.
63·5	4,553	89	89	81	78	Very fair.	Very fine to coarse.	3 ft. 3 in.
63·5	1,892	100	103	96	62	Good.	Very fine to coarse.	3 ft. 3 in.
120	6,084	74	88	79	62	Not very good. This purification was affected by growths. Filter not really quite matured during this experiment.	Coarse.	6 ft.
175	9,065	93	105	89	62	Very fair or fair.	Coarse.	6 ft.
211	10,845	93	105	89	62	Very fair or fair.	Coarse.	6 ft.
50	2,610	101	105	96	84	Good to very good.	Coarse.	6 ft.
500	24,550	98	100	87	77	Good.	Very fine to coarse.	3 ft.
157	5,228	85	108	92	63	Good, apart from solids.	Coarse.	9 ft.
151	4,530	83	92	75	49	Very fair to good.	Coarse.	7 ft. 6 in.

** At the time when the hourly samples were drawn at Chorley, the flow on to the filters was, as stated above, 500 allons per cube yard. The usual flow, however, is about 350 gallons. This latter flow, with an effluent similar to ne above, would be equivalent to 17,185 units of purification. The effluent would probably, however, be of rather igher quality, so the units of purification may be taken at about 18,000, on the average.

†† Comparison of seven chance samples of precipitation liquor with seven chance samples of (nearly) corresponding ffluent. In calculating the strength of the Rochdale precipitation liquor, allowance was made for the abnormal ratio etween "oxygen absorbed" *at once* and *in four hours.*

GEORGE MCGOWAN.
COLIN C. FRYE.

SEPTEMBER, 1907.

ADDENDUM (DECEMBER, 1909).

The foregoing memorandum was sent in to the Commission in the autumn of 1907, very much as it stands now, only a few alterations—and those chiefly of a minor character—having been made in preparing it for the press, and one or two notes added.

In view of the proposed use of a formula for effluents, Dr. Adeney has suggested that it would be desirable to emphasize the two following points:—(1) that the organic nitrogen of a thoroughly well oxidized effluent will to all intents and purposes take up no more oxygen; the organic nitrogen of such an effluent would therefore fall out of the formula for oxidizability of effluents given on p. 12; (2) that most effluents still contain small quantities of unoxidized carbonaceous matter.

There are, of course, comparatively few effluents, at all events from artificial filters, which do not contain a little sewage liquor that has found its way rapidly through the filter. It is to be expected, therefore, that most ordinary effluents will have in them small amounts both of nitrogenous and of carbonaceous organic matter capable of undergoing further oxidation.

With the object of ascertaining at what point the organic nitrogenous matter of a fairly good sewage effluent suffered no further oxidation from dissolved oxygen, the following experiments were made. In Experiments 1, 2, and 3, portions of a Dorking filter effluent were kept in half-full stoppered bottles, which were gently shaken from time to time, while the stoppers were occasionally removed for a few minutes, to allow of the renewal of the air. The fourth experiment (with Rochdale effluent) was done somewhat differently, but it is sufficiently explained in the table of analysis.

The following results were obtained :—

Experiment 1.—Done with coarse percolating filter effluent from Dorking, from the filtration of limed septic liquor. Filtered through Swedish filter paper before analysis; 600 c.c. of the paper-filtered effluent, in each case, were put into half-Winchester stoppered bottles. These were kept at laboratory temperature, and shaken every day.

Drawn	July 6th, 1908. 4 p.m.								
Analysed	July 8th, 1908.	July 20th, 1908.		July 27th, 1908.		August 19th, 1908.		September 21st, 1908.	
Parts per 100,000 *by weight.*		Original.	Again paper-filtered.*	Original.	Again paper-filtered.	Original.	Again paper-filtered.	Original.	Again paper-filtered.
Ammoniacal nitrogen	1·58	0·06	0·06	0·01	0·01	0·01	0·01	0·01	0·01
Albuminoid ,,	0·14	0·07	0·06	0·07	0·06	0·05	0·04	0·05	0·04
Nitrous ,,	0·13	1·50		0·0		0·0		0·0	
Nitric ,,	1·93	1·90		3·60		3·76		3·80	
Total nitrogen by Kjeldahl method	3·81	3·48		3·52		3·68			
Blank	(0·04 in 4·7)	(0·04 in 4·5)		(0·04 in 2·3)					
"X" nitrogen	0·03	−0·05		?		?			
Total Organic nitrogen	0·17	?		?		?			
"Oxygen absorbed" from $\frac{N}{8}$ permanganate at 26·7° C. (80° F.) *at once.*	0·36	1·50		0·24		0·14		0·23	
"Oxygen absorbed" from permanganate at 26·7° C. *after 4 hours.*	1·11	2·63		0·68		0·75		0·61	
Dissolved Oxygen taken up from water in 5 days at 18·3° C. (65° F.)	0·35					0·14			
How this oxygen was added	4 vols. tap water					4 vols. tap water			
REMARKS	The paper-filtered sample was clear and slightly brown in tint; not bright. Earthy smell.	There was now a distinct deposit in bottle, which was loosened by a rubber-tipped rod.		Same as preceding fraction. Earthy smell.		Same as last two fractions.		Same as last three fractions.	

* After this filtration, the effluent was beautifully bright and sparkling.

Experiment 2.—Done with coarse percolating filter effluent from Dorking, from the filtration of limed septic liquor. This effluent was filtered through slow-filtering German paper, before being analysed. Into six bottles, of about 300 c.c. capacity each, 100 c.c. of the paper-filtered effluent were poured. The stoppers were then inserted and the bottles placed in an incubator at 18° C. The bottles were shaken daily.

Drawn (a mixture of 8 hourly samples)	March 23rd, 1908, 8 p.m., to March 24th, 3 a.m.					
		After 20 *Hours.*	3 *Days.*	6 *Days.*	15 *Days.*	19 *Days.*
Analysed	March 27th, 1908.	March 28th, 1908.	March 30th, 1908.	April 2nd, 1908.	April 11th, 1908.	April 15th, 1908.
Parts per 100,000 *by weight.*						
Ammoniacal nitrogen	2·96	2·92	2·97	2·83	0·82	0·02
Albuminoid ,,	0·13	0·15	0·14	0·10	0·14	0·14
Nitrous ,,	0·06	0·04	0·05	0·08	1·25	0·0
Nitric ,,	1·30	1·30	1·31	1·38	1·61	3·84
"Oxygen absorbed" from permanganate at 26·7° C. (80° F.) *at once.*	0·44					
"Oxygen absorbed" from permanganate at 26·7° C. (80° F.) *after 4 hours.*	1·40					
"Oxygen absorbed" from permanganate by sample incubated for 5 days at 26·7° C. (80° F.) *at once.*	0·47					
Nitrous nitrogen after incubation	0·25					
Incubator test (Scudder)	+					
Incubator test, judged by smell	+ {slight earthy odour.					
Dissolved Oxygen taken up from water in 3 and 5 days at 18·3° C. (65° F.)	3 *days.* 0·32 5 *days.* 0·85 Tap water.					
How this oxygen was added	2 vols. 4 vols.					
REMARKS				At this date a very small deposit had settled.		

Experiment 3.—Done with coarse percolating filter effluent from Dorking, from the filtration of limed septic liquor. The effluent was passed through Swedish filter paper before being analysed. Several portions of 600 c.c. each were set aside in bottles of about 1,200 c.c. capacity, and kept at laboratory temperature, with occasional shaking.

Drawn	Wednesday, August 19th, 1908.			
Analysed	August 20th, 1908.	August 25th, 1908.	October 8th, 1908.	
Parts per 100,000 *by weight.*			Original.	After a second paper filtration, on October 8th.
Ammoniacal nitrogen	1·20	1·18	0·01	0·01
Albuminoid ,,	0·13	0·12	0·05	0·03
Nitrous ,,	0·08	0·14	0·0	—
Nitric ,,	1·68	1·66	3·00	—
Total nitrogen by Kjeldahl method	3·32	3·36	3·27	—
Blank	(0·05 in 3·83)	(0·05 in 3·86)	(0·06 in 3·79)	—
"X" nitrogen	0·23	0·26	0·23	—
Total Organic nitrogen	0·34	0·38	0·28	—
"Oxygen absorbed" from permanganate at 26·7° C. (80° F.) *at once*	0·49	0·35	0·08	—
,, ,, ,, ,, ,, *after* 4 *hours*	1·03	1·19	0·75	—
Dissolved Oxygen taken up from water in 5 days at 18·3° C. (65° F.)	0·20	? (6 days)	0·15	—
How this oxygen was added	4 vols. tap water	4 vols. tap water	4 vols. tap water	
REMARKS	The liquid was brownish and slightly opalescent.	Bright and clear, with no suspended matter or deposit.	Bright and clear, with considerable deposit. This was loosened by shaking and by rubbing with a rubber-tipped glass rod.	

Experiment 4.—Done with coarse percolating filter effluents from Rochdale, from the filtration of precipitation liquor.

Drawn	Thursday, June 11th, 1908, 12.5 Noon.		Thursday, June 11th, 1908. 2.5 p.m.	
Analysed	June 12th, 1908.	July 17th, 1908.	June 12th, 1908.	
	Unsettled Effluent.	Same effluent after it had ceased to show any oxygen absorption in an Adeney apparatus. It was then filtered through paper before being analysed.	Settled Effluent, subsequently passed through a small straining filter.	
			Original.	Filtered through paper.
Parts per 100,000 by weight.				
Ammoniacal nitrogen	1·67	0·006		1·87
Albuminoid ,,	0·24	0·05		0·13
Nitrous ,,	0·08			0·08
Nitric ,,	1·52			1·82
Total nitrogen by Kjeldahl method	3·76			4·21
Blank	(0·04 in 2·46)			(0·04 in 2·75)
"X" nitrogen	0·25			0·31
Total Organic nitrogen	0·49			0·44
"Oxygen absorbed" from permanganate at 26·7° C. (80° F.) *at once.*	0·34			0·27
"Oxygen absorbed" from permanganate at 26·7° C. (80° F.) *after 4 hours.*	2·30	0·41		1·90
"Oxygen absorbed" from permanganate by sample incubated for 5 days at 26·7° C. (80° F.) *at once.*	0·68			0·14
Nitrous nitrogen after incubation	0·33			0·16
Incubator test (Scudder)	+			+
Incubator test, judged by smell	+ (earthy)			+ (faint earthy)
Chlorine	9·96			10·00
Solids in suspension	7·4 { 5·2 vol. 2·2 non-vol.		4·3 { 2·8 vol. 1·5 non-vol.	
Parts per 100,000 by volume.				
Solids by centrifuge	133·0		62·4	
Dissolved Oxygen taken up from water at 18·3° C. (65° F.)	3 days. 2·10; 5 days. 4·00; 8 days. 8·00; 12 days. 9·20			3 Days. 0·45; 5 Days. 0·90
How this oxygen was added	Tap water:— 4 vols. 9 vols. 19 vols. 19 vols.			Tap water:— 4 vols. 9 vols.
REMARKS	This effluent was brownish but clear, with a good deal of brown suspended solid. Strong earthy smell.	This paper-filtered sampie was bright and clear.	This sample was brownish but clear, with a small amount of pale brown suspended solids. Faint earthy smell.	

In Experiment 2, the quantities of liquid available only allowed of the "albuminoid" and not of the total organic nitrogen being determined. The albuminoid nitrogen remained constant throughout, but the remaining portion of the organic nitrogen (the "X" nitrogen) probably suffered diminution.

In Experiments 1 and 3, the albuminoid nitrogen of the paper-filtered effluents, which at the start amounted to 0·14 and 0·13 parts per 100,000, was reduced in each case to 0·05 part, and further reduced, after paper filtration of the completely oxidized effluent, to 0·04 and 0·03. Experiment 4, which deals with the Rochdale effluent, gave 0·05 part albuminoid nitrogen for the fully oxidized effluent, after paper filtration. It thus corroborated Experiments 1 and 3. From these latter it may therefore be permissible to argue the point in question.

The Dorking sewage being a domestic sewage of about average strength, the effluents from the filtration of the limed septic liquor there may be considered as fairly representative (so far as organic nitrogen is concerned) of such sewages.

The difficulties attending the *indirect* determination of small quantities of organic nitrogen in effluents containing practically all their nitrogen in the form of nitrate, this being present in relatively large amount, make it inadvisable to take into consideration here the figures for organic nitrogen given in Experiments 1 and 3. We may, however, with a reasonable degree of accuracy, take the total organic nitrogen as being two to three times as great as the "albuminoid" nitrogen. On this assumption, the foregoing analytical results—so far as they go—show that the liquid portion of a *thoroughly* oxidized effluent from an average strength sewage will, after paper filtration, contain about 0·04 to 0·05 part albuminoid nitrogen per 100,000, or, say, 0·1 to 0·15 part of total organic nitrogen.

When dealing with well oxidized effluents derived from sewages of average strength, therefore, some such quantity as this of organic nitrogen may probably be neglected altogether in the formula for oxidizability of effluents.

On the other hand, as has been already said, there are very few sewage effluents from artificial filters which do not contain small, but still appreciable, quantities of oxidizable carbonaceous matter, because of a little of the sewage liquor getting through the filter too quickly.

A formula for the oxidizability of filter effluents, derived from more or less normal sewages, which would therefore be more correct in theory than that given on p. 12, would be :—

$$(\text{Ammon N.} \times 4{\cdot}5) + (\text{Organic N. (in excess of } 0{\cdot}1 \text{ to } 0{\cdot}15) \times 4{\cdot}5) + (\text{Ox. abs. in 4 hrs.} \times ?) + (\text{Vol. solids} \times ?) - (\text{Nitric N.} \times 3).$$

Or, perhaps, better, as suggested to us by Dr. Adeney :—

$$(\text{Ammon. N.} \times 4{\cdot}5) + \{\text{Ox. abs. in 4 hrs. (in excess of } 0{\cdot}75 \text{ to } 1{\cdot}0) \times 6{\cdot}5\} + (\text{Vol. solids} \times ?).^*$$

In the meantime, for practical purposes, and with the proviso that the formula given on p. 12 is an empirical one and is not absolutely correct in theory, we think that it may be accepted as giving a fair approximation to the truth. The following table, which refers almost entirely to the effluents already quoted on p. 11, illustrates this :

* *Cf.* Letts and Adeney, App. VI. to Fifth Report of the Commission, p. 42.

Place.	Kind of Effluent.	Parts per 100,000. Ammon. Nitrogen.	Total Organic Nitrogen.	Volatile Solids.	Dissolved oxygen absorption, by experiment.	Dissolved oxygen absorption, as calculated by formula.
	Jointed Samples.					
Rochdale -	No. 3688. Settled Percolation Effluent.	0·07	0·38	2·6	5·52	7·23
„ -	„ „ paper-filtered.	0·07	probably about 0·3	—	2·54	about 3·0
„ -	No. 3699. Unsettled Percolation Effluent.	0·59	say, 0·46*	5·3	9·68	15·3
Caterham -	No. 17. Paper-filtered	3·50	say, 0·8†	1·6	20·7	22·6
Accrington -	No. 464. Sec. contact Effluent.	1·92	0·71	4·2	about 20·0	20·2
„ -	„ Paper-filtered	1·78	0·42	—	10·78	9·9
„ -	No. 611. Prim. contact Effluent.	1·12	0·79	6·0	19·74	20·6
„ -	„ Paper-filtered	1·12	say, 0·4‡	—	8·82	6·8
„ -	No. 615. Prim contact Effluent.	0·55	0·36	1·5	8·24	7·1
„ -	„ Paper-filtered	0·55	say, 0·25‡	—	5·68	3·8
	Unjointed Samples.					
Rochdale -	No. 3693. Percolation Effluent, paper-filtered.	say, 0·1‡	say, 0·25‡	—	1·75	1·6
„ -	No. 3694. Percolation Effluent.	0·14	say, 0·5§	2·5	7·59	7·9
Kingston -	No. 751. Prim. contact Effluent.	0·59	0·23	say, 0·8‖	5·78	5·2

We trust that this memorandum may be found of some practical use for the calculation of the work done by filters dealing with sewage liquors of different strengths. With further investigation of the subject, a formula more nearly correct in theory will, no doubt, be arrived at.

For the determination of the oxidizability of effluents, in relation to their effect upon the water of streams, the rate of oxidation shortly after the discharge is, no doubt, the most important point (apart from the question of deposition of solids).

SECOND ADDENDUM (*December, 1909*).

With regard to the *calculation of units of purification per cube yard of filter,* we think—on further consideration—that it would be more correct *not* to give credit for the nitrate remaining in the effluent. The strength of a sewage liquor is based upon the amount of oxygen required for the complete oxidation of the liquor by atmospheric or dissolved oxygen, the nitrogen (at all events, much the greater part of it) remaining in the diluted liquid in the form of nitrate.

To give credit for the nitrate in an effluent, *in calculating the work done by a filter* (and apart from the question of considering the putrescibility of a given effluent), is therefore equivalent to counting this (effluent) nitrate twice.

The effect of this alteration would be to introduce a new column D. (a^1) into Table II., and to lower the values for columns E, G and G^1.

The following two examples will make the point clear. The figures in the upper lines are in each case copied from Table II. as it now stands; the lower line shows the alteration now proposed, the *underlined* figures being the new ones.

* Albuminoid Nitrogen = 0·23.
† Albuminoid Nitrogen = 0·26.
‡ This is an assumption from the figures of the original effluent.
§ Albuminoid Nitrogen = 0·18.
‖ Deduced, approximately, from centrifuge figure.

A	B	C				D				E	F	G	G¹			
		Filter Effluent ; Figures of Analysis.				Strength or oxidizability of Filter Effluent.							Percentage Purification :—			
						(a)	(a¹)	(b)	(c)				(a)	(b)	(c)	(d)
Place.	Calculated strength of liquor treated.	Ammoniacal + Organic Nitrogen.	Volatile solids.	"Oxygen absorbed" from Permanganate in 4 hours.	Nitric Nitrogen.	Whole effluent, including suspended solids.	Effluent without Nitrate.	Effluent without suspended solids.	Effluent without suspended solids and Nitrate.	Oxygen used up in producing this effluent. B–D (a) or B–D (a¹)	Gallons of liquor treated per cube yard of filter per day (dry weather flow or constant flow).	Units of purification per cube yard of filter.	On atmospheric Oxygen taken up in the process.	On atmospheric Oxygen taken up, leaving out of account the suspended solids of the effluent.	On atmospheric Oxygen taken up, leaving out of account the suspended solids and Nitrate of the effluent.	On Oxygen absorbed from Permanganate in 4 hours (including the suspended solids of the effluent).
Septic Liquor and Double Contact.																
GUILDFORD - - -	125 125	1·7 ap. 1·7 ap.	1·0 ap. 1·0 ap.	2.77 2·77	1·17 1·17	6·2	 9·7	4·2	7·7	118·8 115·3	22·7 22·7	2697 2617	95 92	97 94	94 94	76 76
Septic Liquor and Percolation.																
ACCRINGTON—																
Experiment II.																
Strong Liquor - - -	81·2 81·2	0·79 0·79	1·5 1·5	1·54 1·54	3·25 3·25	– 3·2	 6·6	– 6·2	3·6	84·4 74·6	100 100	8440 7460	104 92	108 96	96 96	81 81

We have not attempted to introduce this correction into any of the reports in this Appendix, partly because this would complicate the references to the point in the Fifth and Sixth Reports of the Commission, and partly because of the time and labour which it would now involve.

It does not materially alter the main conclusions arrived at. Of course, the larger the amount of nitrate in the effluent in question, the greater would be the difference between the old and the new figures for units of purification, etc.

We propose, in future, to adopt this revised plan.

G. M.
C. C. F.

ACCRINGTON EXPERIMENTS.

By Dr. G. McGowan and Mr. Colin C. Frye.

Prefatory Note.

Since the results of the following experiments are for the most part given in terms of " strength " of sewage liquor and of " oxidizability " of filter effluent, reference should be made in the first instance to the two papers on those subjects in this Appendix, pp. 1 and 10.

The main object of the experiments at Accrington, which extended from May, 1905, to June, 1908, was to determine whether it is easier to treat efficiently a strong or a weak sewage liquor upon percolating filters and upon contact beds, respectively, the aggregate amount of oxidizable impurity in both liquors being the same, and only the dilution varying. At the same time a direct comparison was to be made of the volumes of the same sewage liquor which could be treated upon percolating filters and upon contact beds. The third, fourth and fifth experiments were done with the object of seeing *how much* strong and weak liquor the percolating filters were capable of treating, still with the production of a good effluent.

The liquor treated throughout was the Accrington septic tank liquor, either by itself or diluted with water. The filters were :—

Two percolating filters of coarse material, each 10 feet in diameter and 6 feet deep ;

Two primary contact beds of medium to coarse material, each 10 feet long by 9 feet broad and 4 feet deep ;

Two secondary contact beds of fine material, each 10 feet long by 9 feet broad and 4 feet deep.

The following experiments were carried out :—

Experiment I.—Comparative treatment on percolating filters and contact beds of (*a*) 100 gallons per cube yard per 24 hours of strong septic tank liquor and (*b*) 100 gallons of strong liquor + 100 gallons of water = 200 gallons of weak liquor. The *actual average* rates on the two pairs of contact beds were 72·2 and 148·8 gallons per day, the beds treating strong liquor being filled twice a day and those treating weak liquor four times a day. Broadly speaking, the contact beds only treated in this experiment three-fourths of the amounts treated by the percolating filters, owing partly to the original water capacity of the beds (at two fillings per day) being less than 100 gallons per cube yard and partly to their gradual loss of capacity. At the commencement of the experiment, two fillings per day on the pair treating strong liquor were equivalent to 90 gallons per cube yard, and four fillings per day on the pair treating weak liquor were equivalent to 179 gallons.

Duration of experiment :—May 5th, 1905, to June 30th, 1906.

Experiment II.—Comparative treatment on percolating filters and contact beds of (*a*) 100 gallons per cube yard per 24 hours of strong septic tank liquor and (*b*) 50 gallons of strong liquor + 50 gallons of water = 100 gallons of weak liquor.

The *actual average* rates on the contact beds were 51·6 and 57·9 gallons.

Duration of experiment :—July 2nd, 1906, to March 23rd, 1907.*

* Strictly speaking, this second experiment ought to date from June 7th, 1906, instead of July 2nd, and it ought to include the set of samples (Nos. 427–440) drawn upon June 13th of that year. The inclusion of this set with the other eight sets of Experiment II. would make a little difference in the *average* figures of analysis, and it would also give 10 instead of 9 months for the loss of capacity of the contact beds. In view of the comparative smallness of these differences, however, it has not been thought worth while to recalculate the results of this experiment.

Experiment III.—Comparative treatment on percolating filters *alone* of (*a*) 125 gallons per cube yard per 24 hours of strong septic tank liquor and (*b*) 125 gallons of strong liquor + 125 gallons of water = 250 gallons of weak liquor.

Duration of experiment :—April 8th to June 7th, 1907.

Experiment IV.—Comparative treatment on percolating filters alone of (*a*) 200 gallons per cube yard per 24 hours of septic tank liquor and (*b*) 200 gallons of septic tank liquor + 200 gallons of water = 400 gallons of weak liquor.

Duration of experiment :—June 10th to October 26th, 1907.

Experiment V.—Comparative treatment on percolating filters alone of (*a*) 250 gallons per cube yard per 24 hours of septic tank liquor and (*b*) 250 gallons of septic tank liquor + 250 gallons of water = 500 gallons of weak liquor.

Duration of experiment :—October 28th, 1907, to June 18th, 1908.

Sampling.

Percolating Filters.—The samples of septic tank liquor were drawn every fifteen days (Sundays excepted), one hour later on each successive day. The samples of percolation effluent were taken from 15 to 30 minutes after those of septic liquor, so as to correspond as nearly as possible with the latter.

Contact Beds.—The samples of septic tank liquor were drawn when the beds were half full, every fifteen days, as above. The effluents were all drawn at mid-flow. Those from the contact bed treating strong liquor were taken at one filling later on each successive occasion, and those from the contact beds treating weak liquor at two fillings later.

The paper-filtered samples of effluent, both in this and in the succeeding experiments, were filtered through Swedish filter-paper by Mr. Boothman at the time the samples were drawn.

"Strength" of the Septic Tank Liquor.

Attention may be drawn, in passing, to the corroboration obtained here of the soundness of the formula (No. 1), given on page 4 of the Memorandum dealing with the calculation of the relative "strengths" of sewage liquors, at all events, of sewage liquors of the same nature. In the Accrington experiments every care was taken to keep the dilutions for the filters treating weak liquor as nearly accurate as might be, though it was of course impossible to make them quite as exact as in a laboratory experiment.

The chlorine figure in this case was an admirable check as regards the dilution, since it was determined both in the tank liquors themselves and in the corresponding samples of town's water. The chlorine of the water (which varied from about 1·2 to 1·5 parts per 100,000), being deducted from the total chlorine found in any tank liquor, gave the chlorine due to the sewage of the tank liquor alone. The following figures were thus obtained for the first three experiments. The figures in brackets indicate the number of estimations in each case :—

Experiment.	I.	II.	III.*
"Strong" tank liquor going on to percolating filter -	† 7·51 (24)	8·13 (8)	5·87 (5)
"Weak" ,, ,, ,, ,, ,, ,, -	† 4·19 (24)	4·01 (8)	3·02 (5)
"Strong" tank liquor going on to contact beds -	† 7·52 (24)	7·96 (8)	
"Weak" ,, ,, ,, ,, ,, ,, -	† 3·67 (24)	4·08 (8)	

* During Experiment III. the chlorine in the town's water was not estimated, but 1·3 has been assumed as being nearly a correct average, judging from the estimations made during Experiments I and II.

† Omitting from the averages the abnormal chlorine figures obtained from the four corresponding samples, Nos. 274, 277, 280, and 284, viz., 21·2, 11·1, 19·4, and 11·1.

The chlorine figure varied from about one-tenth to one-fourteenth of the "strength" figure, thus :—

Experiment.	I.		II.		III.	
	(a)	(b)	(a)	(b)	(a)	(b)
"Strong" tank liquor going on to percolating filter -	85·2	7·51	81·2	8·13	79·0	5·87
"Weak" " " " " " " -	48·9	4·19	40·5	4·01	42·4	3·02
"Strong" tank liquor going on to contact beds -	85·7	7·52	83·3	7·96		
"Weak" " " " " " " -	42·0	3·67	42·2	4·08		

(a) = Calculated "strength." (b) = Chlorine.

If now, for the purpose of comparison, the chlorine figure in the *strong* liquors is made equal to the corresponding "strength" figure, and if the *proportionate* chlorine in the weak liquors is calculated, it is seen how very nearly the corresponding figures for "strength" and for chlorine agree in every case, thus :—

Experiment.	I.		II.		III.	
	(a)	(b)	(a)	(b)	(a)	(b)
"Strong" tank liquor going on to percolating filter -	85·2	85·2	81·2	81·2	79·0	79·0
"Weak" " " " " " " -	**48·9**	**47·5**	**40·5**	**40·1**	**42·4**	**40·6**
"Strong" tank liquor going on to contact beds -	85·7	85·7	83·3	83·3		
"Weak" " " " " " " -	**42·0**	**41·8**	**42·2**	**42·7**		

The respective pairs of figures (a) and (b), in thick type, are those to which attention is drawn. We think that they constitute an additional strong proof of the correctness of the formula given for calculating the relative "strengths" of septic tank liquors, at all events of tank liquors from domestic sewages, since these may be taken broadly as being more or less of the same composition organically, only differing largely so far as diluting water is concerned.

Experiment I.

This experiment extended over about 14 months and consisted in the comparative treatment on percolating filters and double contact beds of strong and weak septic tank liquor, the volume of weak liquor treated being twice that of the strong, but the actual amount of organic impurity being the same in both cases.

The average rates of treatment throughout the experiment were :—

	Gallons per cube yard per 24 hours.
Percolating filter treating strong liquor - - - - - - - -	100
" " " weak " - - - - - - - -	200
Double contact beds treating strong liquor - - - - - - -	72·2
" " " " weak " - - - - - - -	148·8

The septic tank liquors treated gave the following average analyses, the minimum and maximum figures being also stated ; the figures in brackets indicate the number of estimations in each case :—

Parts per 100,000.	Percolating Filters.		Contact Beds.	
	Strong Liquor.	Weak Liquor.	Strong Liquor.	Weak Liquor.
Ammoniacal Nitrogen - - - - -	1·38 to 8·07 = 4·75 (7)	0·76 to 6·14 = 2·93 (8)	3·48 to 7·97 = 4·86 (6)	1·64 to 4·09 = 2·35 (6)
Albuminoid Nitrogen - - - - -	0·33 to 1·36 = 0·71 (7)	0·29 to 0·88 = 0·43 (8)	0·49 to 1·42 = 0·91 (6)	0·29 to 0·82 = 0·41 (6)
Total Organic Nitrogen - - - - -	0·75 to 2·76 = 1·58 (7)	0·52 to 1·71 = 0·84 (8)	1·09 to 2·05 = 1·44 (6)	0·62 to 1·16 = 0·81 (6)
Total Nitrogen (by Kjeldahl) - - - -	1·96 to 10·48 = 6·12 (25)	1·00 to 7·85 = 3·32 (24)	2·19 to 10·02 = 6·10 (25)	0·95 to 5·25 = 2·91 (23)
"Oxygen absorbed" from $\frac{N}{8}$ Permanganate at 27° C. *at once*	1·14 to 4·42 = 2·63 (25)	0·68 to 2·89 = 1·35 (25)	1·19 to 4·62 = 2·62 (25)	0·51 to 1·63 = 1·19 (25)
Do. do. *in 4 hours* - -	4·30 to 12·75 = 8·87 (25)	2·63 to 10·16 = 5·09 (25)	4·30 to 14·08 = 8·96 (24)	2·09 to 6·59 = 4·44 (25)
Chlorine (after deducting the Chlorine of the town's water).	2·96 to 11·86 = 7·51 (24)	1·60 to 9·70 = 4·19 (24)	2·98 to 11·86 = 7·52 (24)	1·21 to 6·14 = 3·67 (24)
Solids in suspension - - - - - -	9·0 to 21·3 = 14·2 (25)	4·2 to 18·8 = 8·2 (25)	11·3 to 23·7 = 14·5 (25)	4·1 to 12·4 = 7·2 (25)
Volatile matter in those solids - - - -	4·4 to 17·0 = 10·0 (25)	3·4 to 11·9 = 5·7 (24)	4·9 to 16·6 = 10·0 (24)	2·8 to 8·9 = 5·4 (25)
Solids by Centrifuge (vols.) - - - -	26·2 to 153·6 = 64·9 (25)	10·4 to 92·2 = 37·0 (25)	22·6 to 138·8 = 66·5 (25)	17·2 to 74·0 = 34·9 (25)
Ratio of solids in suspension to Centrifuge Solids	1 : 2·5 to 1 : 10·7 = 1 : 4·6 (25)	1 : 1·6 to 1 : 7·3 = 1 : 4·5 (25)	1 : 2·2 to 1 : 9·7 = 1 : 4·5 (25)	1 : 2·5 to 1 : 10·3 = 1 : 4·9 (25)

The filter effluents obtained gave the following average analyses, the minimum and maximum figures being also stated; the figures in brackets indicate the number of estimations in each case :—

Parts per 100,000.	Percolating Filter Treating Strong Liquor.		Percolating Filter Treating Weak Liquor.		Contact Bed Treating Strong Liquor.			Contact Bed Treating Weak Liquor.		
	Original Effluent.	Effluent after Filtration through Paper.	Original Effluent.	Effluent after Filtration through Paper.	Primary Effluent.	Secondary Effluent.	Secondary Effluent after Filtration through Paper.	Primary Effluent.	Secondary Effluent.	Secondary Effluent after Filtration through Paper.
Ammoniacal Nitrogen - - - - - - -	0·03 to 5·09 = 0·98 (15)		0·01 to 5·31 = 0·77 (15)		0·76 to 5·99 = 2·86 (11)	0·28 to 4·00 = 1·56 (19)		0·28 to 1·79 = 1·10 (10)	0·02 to 2·23 = 0·55 (19)	
Albuminoid Nitrogen - - - - - - -	0·08 to 1·25 = 0·32 (15)		0·07 to 0·88 = 0·20 (15)		0·17 to 0·75 = 0·46 (11)	0·13 to 0·66 = 0·31 (19)		0·10 to 0·29 = 0·21 (10)	0·05 to 0·35 = 0·13 (19)	
Total Organic Nitrogen - - - - - - -	0·17 to 2·15 = 0·81 (9)		0·20 to 1·45 = 0·66 (8)		0·39 to 1·35 = 0·78 (9)	0·36 to 0·98 = 0·68 (11)		0·22 to 1·00 = 0·44 (5)	0·13 to 0·62 = 0·31 (10)	
Nitrous Nitrogen - - - - - - - -	0·01 to 0·80 = 0·19 (24)		0·00 to 0·45 = 0·10 (22)		0·00 to 0·58 = 0·03 (25)	0·00 to 1·34 = 0·31 (25)		0·00 to 0·06 = 0·00 (24)	0·00 to 0·32 = 0·07 (25)	
Nitric Nitrogen - - - - - - - -	0·63 to 3·89 = 2·26 (24)		0·13 to 2·34 = 1·56 (24)		0·00 to 0·24 = 0·06 (25)	0·00 to 1·95 = 0·66 (25)		0·00 to 0·60 = 0·10 (24)	0·00 to 1·16 = 0·65 (25)	
Total Nitrogen (by Kjeldahl) - - - - - -	2·14 to 8·65 = 4·01 (14)		1·45 to 6·97 = 3·15 (11)		1·60 to 7·36 = 3·49 (16)	1·94 to 3·96 = 2·93 (13)		0·84 to 2·57 = 1·58 (13)	0·71 to 2·61 = 1·46 (13)	
"Oxygen absorbed" from $\frac{N}{8}$ Permanganate at 27° C. *at once*	0·08 to 2·76 = 0·96 (25)	0·15 to 0·86 = 0·47 (21)	0·17 to 2·17 = 0·65 (25)	0·03 to 1·34 = 0·33 (21)	0·44 to 2·43 = 1·34 (25)	0·31 to 2·01 = 1·01 (25)	0·19 to 0·73 = 0·43 (11)	0·15 to 0·84 = 0·56 (24)	0·08 to 0·73 = 0·39 (25)	0·05 to 0·42 = 0·23 (11)
" " " " *in 4 hours*	0·80 to 10·07 = 3·39 (25)	0·62 to 2·79 = 1·68 (21)	0·86 to 7·41 = 2·28 (25)	0·41 to 3·43 = 1·19 (21)	1·66 to 7·53 = 4·64 (25)	1·24 to 5·65 = 3·13 (25)	0·73 to 2·61 = 1·62 (11)	0·83 to 3·41 = 2·19 (23)	0·49 to 2·31 = 1·42 (24)	0·46 to 1·21 = 0·87 (11)
Incubator test (by smell) - - - - - - -	23 * + (23)	21 + (21)	23 + (23)	21 + (21)	25 — (25)	9 +, 15 —, 1 ? (24)	9 +, 2 ? (11)	18 –, 3 +, 1 ? (22)	21, + 3 –, 1 ? (25)	11 +, (11)
Chlorine (after deducting the Chlorine of the town's water)	2·58 to 11·48 = 7·35 (22)		1·54 to 9·00 = 4·32 (22)		3·55 to 11·62 = 7·86 (18)	3·55 to 11·48 = 7·46 (21)		1·50 to 5·42 = 3·64 (16)	1·40 to 5·76 = 3·70 (21)	
Dissolved Oxygen taken up in 24 hours at 18° C. - -	0·17 to 2·13 = 0·78 (23)	0·04 to 0·82 = 0·30 (22)	0·12 to 3·12 = 0·59 (23)	0·01 to 1·19 = 0·28 (21)	0·46 to 8·96 = 3·53 (18)	0·19 to 4·33 = 1·34 (22)	0·31 to 1·26 = 0·61 (11)	0·23 to 2·43 = 1·25 (19)	0·16 to 1·56 = 0·51 (21)	0·09 to 0·60 = 0·31 (10)
Dissolved Oxygen taken up in 5 days at 18° C. - -		0·59 to 3·19 = 1·41 (6)		0·41 to 1·91 = 1·02 (5)			0·92 to 3·05 = 1·88 (4)			0·60 to 1·33 = 1·01 (4)
Solids in suspension - - - - - - -	1·0 to 36·0 = 8·2 (24)		1·3 to 23·4 = 5·7 (22)		4·1 to 11·4 = 6·29 (23)	2·5 to 9·3 = 5·2 (13)		2·4 to 7·0 = 4·1 (12)	3·4 and 3·6 (2)	
Volatile matter in these solids - - - - -	0·8 to 22·4 = 5·4 (24)		1·0 to 15·5 = 3·9 (22)		2·8 to 10·0 = 5·00 (22)	0·3 to 8·4 = 4·1 (13)		1·5 to 4·6 = 3·1 (12)	1·6 and 3·1 (2)	
Solids by Centrifuge (vols.) - - - - - -	23·5 to 254·0 = 81·1 (22)		10·4 to 266·0 = 54·3 (24)		10·4 to 65·5 = 25·6 (25)	9·0 to 64·0 = 35·1 (22)		4·8 to 35·2 = 15·4 (24)	2·4 to 38·0 = 13·9 (22)	
Ratio of solids in suspension to Centrifuge solids - -	1 : 5·8 to 1 : 23·5 = 1 : 11·0 (22)		1 : 7·3 to 1 : 30·7 = 1 : 10·8 (21)		1 : 1·6 to 1 : 9·4 = 1 : 4·2 (23)	1 : 3·2 to 1 : 20·4 = 1 : 9·4 (12)		1 : 1·2 to 1 : 9·4 = 1 : 3·8 (12)		

* The sign " + " means that the sample passed the incubator test; the sign " — " that it failed to pass; and the sign " ? " that it had a doubtful smell after incubation.

The figures for strength of liquor* treated and for suspended solids, therefore, were :—

	Percolating filters.		Contact beds.	
	Calculated strength.	Suspended solids.	Calculated strength.	Suspended solids.
Strong liquor - - - - -	85·2	14·2 (25)	85·7	14·5 (25)
Weak liquor - - - - -	48·0	8·2 (25)	42·0	7·2 (25)

A.—*Work done by the Percolating Filters.*

The figures given on Table II., pp. 30–31, of the Memorandum on the Estimation of the Work done by Filters,† for relative purification effected by the percolating filters, treating 100 gallons of strong and 200 gallons of weak septic tank liquor, respectively, per cube yard per 24 hours, were almost equal to one another, viz., 7,310 and 7,680 units‡ The filter treating weak liquor shows the slightly higher aggregate purification figure, but on the other hand this filter was treating a liquor rather stronger than it should have been (calculated strength 48 instead of 43), in consequence of which its *percentage* purification figure is only 80, as against 86 for the filter treating strong liquor.§

Within the limits of strength of liquor and of volume treated in the two cases, there was therefore very little difference in the actual *work done* by the two percolating filters.

It will be noted from this and subsequent experiments that, other things being equal, a greater aggregate purification per cube yard, as measured by the actual *amount* of oxygen used up, is effected when the final product is an *imperfectly* oxidized effluent. This is of course what one would naturally expect, for, in such a complex mixture as sewage or sewage liquor, some of the organic compounds present must be more easily and quickly oxidized than others. The indications also are that, unit for unit, the first or carbon stage of the oxidation is, under the conditions of filtration, easier, or at least quicker, and therefore presumably requires less expenditure of energy than the second or nitrification stage.

B.—*Work done by the Contact Beds.*

(1) *Primary Beds of Medium to Coarse Material.*—The primary bed treating 297·6 gallons per cube yard per day of weak liquor gave practically the same result as the primary bed treating 144·4 gallons of strong liquor, as regards aggregate purification (7,380 units,‖ as against 7,249), the percentage purifications being 60 and 59. The "strengths" of the liquors treated were nearly proportional, viz., 42·0 and 85·7.

(2) *Secondary Beds of Fine Material.*—Here the bed treating weak liquor gave distinctly better results than the bed treating strong liquor, as regards units of purification, which for the primary and secondary beds together amounted to 5,654‖ and 5,011 units in the two cases, the percentage purifications being 91 and 81. Fully two-thirds of the total impurity was removed by the primary bed treating strong liquor and nearly two-thirds by the primary bed treating weak liquor. The actual purification by the secondary bed treating strong liquor was 1,386 units, and by the secondary bed treating weak liquor 1,964 units.

This would therefore seem to indicate that, so long as water-logging is avoided, *i.e.*, so long as contact beds are given sufficient time to drain and to rest, somewhat better purification results are obtained by treating two volumes of weak septic tank liquor on beds 3 feet deep, the primary bed being of medium to coarse material and the secondary bed of

* Calculated according to the formula :—(Ammon. + Organic N.) × 4·5 + (Ox. abs. in 4 hrs. × 6·5).

† This Appendix, p. 10 *et seq.*

‡ The number of "units of purification" (a term which we venture to introduce here) is obtained by deducting from the "strength" figure of the septic tank liquor the "strength" or oxidizability figure of the effluent, and multiplying the figure so obtained, which represents the amount of oxygen used up, by the number of gallons treated per cube yard of filter per day (dry weather flow or constant flow, as the case may be).

§ These and subsequent figures for percentage purification are based on the amount of atmospheric oxygen used up in the filtration process for the oxidation of *both* the carbon and the nitrogen compounds present in the sewage liquor, as calculated by the formulæ for strength of liquor and for oxidizability of effluent. If, theoretically, 100 parts by weight of oxygen are required by a given volume of sewage for its conversion into a completely oxidized effluent, then "80 per cent. purification" means that 80 parts of atmospheric oxygen have been taken up.

‖ Owing to an error. the figure 7,678 was given for the Fifth Report of the Commission, p. 111, instead of 7,380, and the figure 5,803 instead of 5,654.—G. M.

fine material, than one volume of strong liquor, the total organic impurity, inclusive of the total suspended solids, being the same in both cases.

The probable explanation of this is that (*a*) the two volumes of (weak) liquor treated can hold in solution twice as much oxygen as the one volume of (strong) liquor, and, further, (*b*) with four fillings per day in place of two, more oxygen must be mechanically carried into the bed with the larger volume. Thus, 100,000 parts of water, fully aerated, hold in solution about 1 part by weight of oxygen (equivalent to 7 c.c. of oxygen per litre). Sewage or septic tank liquor entering a contact bed would not aerate itself to this extent, but it would take up a certain amount of oxygen. We have no data for offering an opinion as to how much additional oxygen would be actually carried into a bed by the "injector" action of the divided liquid, but this may possibly be very appreciable. If 100 gallons of liquor are treated on a cube yard per day, then 1 part of oxygen (per 100,000 of liquor) multiplied by 100 represents the equivalent of 100 "units of purification."

If, therefore, the resting period (during which, as Dr. Fowler has shown, the bacterial jelly of a bed rapidly absorbs oxygen) is long enough in both cases to allow of the oxidation of the readily fermentable portions of the solid carbonaceous matter caught in the bed, and the nitrification of the nitrogenous matter, with resulting accumulation of nitrate, the beds treating the larger volume of weak liquor must hold the advantage, for the reasons just specified.

The *aggregate* loss of capacity in the two sets of beds, during the time that this experiment lasted, was almost the same in both, but in the case of the beds treating strong liquor this loss took place almost entirely in the primary bed, while in the case of the beds treating weak liquor the secondary bed also suffered to some extent, thus :—

	Capacity in Gallons.	
	At beginning of Experiment, May 3rd, 1905.	At end of Experiment, June 6th, 1906.
Primary bed treating strong liquor - - -	1,170	735
Primary bed treating weak liquor - - -	1,185	780
Secondary bed treating strong liquor - - -	1,035	1,030
Secondary bed treating weak liquor - - -	1,030	950
Total loss in capacity of primary and secondary beds treating strong liquor.	20 per cent. of the original water capacity.	
Total loss in capacity of primary and secondary beds treating weak liquor.	22 ,, ,, ,, ,,	

That the secondary bed treating weak tank liquor lost capacity to a greater extent than the corresponding bed treating strong liquor was no doubt due to the fact that the two volumes of dilute primary effluent contained about 9·3 * parts of suspended solids, as against 7·4 * parts in the one volume of strong primary effluent, owing to the more frequent filling and emptying of the weak liquor beds.

Comparison of the Work done by the Percolating Filters and the Contact Beds.

The percolating filters effected a much greater actual *amount* of purification per cube yard of filtering material than the double contact beds, the respective figures being :—

	Units of Purification.	Percentage Purification.
Percolating filter treating strong liquor - - -	7,310	86
Double contact beds treating strong liquor - - -	5,011	81
Percolating filter treating weak liquor - - - -	7,680	80
Double contact beds treating weak liquor - - -	5,654	90

* These figures are averages from eleven pairs of corresponding samples.

Filter Effluents from the Strong and the Weak Liquors.

As regards the quality of the two strong liquor effluents, *suspended solids included*, the results were slightly in favour of the percolating filter effluent, which still required 12 parts of oxygen per 100,000 for its complete oxidation, while the contact effluent required 16 parts. If we *eliminate the solids* in both cases, the oxidizability of the liquid alone would be approximately represented by 2 parts of oxygen in the case of the percolating filter effluent and 8 parts in the case of the contact bed effluent. This superiority of the percolating filter effluent, so far as lesser (ultimate) oxidizability is concerned, was partly due to the fact that it contained 2·4 parts of nitric (plus nitrous) nitrogen, as against 1 part in the contact bed effluent; but, even apart from this, it was rather the better, the actual oxidizable matter left in the liquid being equivalent to about 8·5 parts of oxygen, while that in the contact bed effluent was equivalent to about 10 parts.

In the case of the two weak liquor effluents, suspended solids included, the results were in favour of the double contact bed effluent, which only required 4 parts of oxygen for its complete oxidation, as against 9·5 parts for the percolating filter effluent. If we eliminate the solids, there is practically no difference in the quality of the two effluents, both of them being well oxidized. If both solids and nitrate are eliminated, the double contact bed effluent is again rather the better, with an oxidizability figure of 4, as against 6·5 for the percolating filter effluent.

The above results may be approximately tabulated as follows, both for the effluents from the strong and the weak tank liquors :—

	Effluents from Strong Liquor.		Effluents from Weak Liquor.	
	Percolation.	Double Contact.	Percolation.	Double Contact.
	Parts of	*oxygen per*	100,000 *parts*	*of effluent.*
Oxidizability of whole effluent, including solids and giving credit for nitrate - - -	12	16	9·5	4·0
Oxidizability of effluent, without its suspended solids and giving credit for nitrate - -	2	8	2·0	2·0 ap.
Oxidizability of effluent, without solids and giving no credit for nitrate - - - - - -	8·5	10	6·5	4·0

The quality of the effluents *without their suspended solids*, as regards taking up of dissolved oxygen in 24 hours and incubation, is shown by the following average figures :—

	Effluents from Strong Liquor.		Effluents from Weak Liquor.	
	Percolation.	Double Contact.	Percolation.	Double Contact.
Dissolved oxygen taken up from water in 24 hours at about 18° C. (65° F.) - - - - -	0·30 (22) 0·37 (12)	0·61 (11)	0·28 (21) 0·30 (11)	0·31 (10)
Incubation (by smell) - - - - - - -	All passed (25).	All passed (11).	All passed (21).	All passed (10).

Summary of Experiment I.

A.—*Filters Treating Strong Liquor.*

Under the conditions of the experiment, the percolating filter treating strong liquor (strength = 85·2; suspended solids = 14·2) did $1\frac{1}{2}$ times as much actual work (*i.e.*, oxidation) per cube yard as the double contact beds treating strong liquor (strength = 85·7; suspended solids = 14·5). The working power of the percolating filter remained unimpaired at the end of the 14 months during which the experiment

lasted, while the contact beds lost in that time one-fifth of their original water capacity. Apart from suspended solids, the percolating filter effluent may be described as good and the secondary contact bed effluent as fair, the average quantities of dissolved oxygen taken up in 24 hours by the two being about 0·3 and 0·6 parts, respectively.

B.—*Filters Treating Weak Liquor.*

The percolating filter treating weak liquor (strength = 48·0; suspended solids = 8) did $1\frac{1}{3}$ times as much work per cube yard as the double contact beds treating weak liquor (strength = 42·0, suspended solids = 7·2), the latter having eventually lost one-fifth of their water capacity. Both effluents were good, taking up only about 0·3 part of dissolved oxygen from water in 24 hours; the secondary contact bed effluent held, however, a slight advantage over the percolating filter effluent as regards lesser total oxidizability.

EXPERIMENT II.

In this experiment the percolating filter treating strong liquor continued to receive the same volume as in Experiment I., *i.e.*, 100 gallons per cube yard per day, and the contact beds treating strong liquor continued to have two fillings, which were now equivalent, however, to an *average* of only 51·6 gallons per cube yard per day during the time that the experiment lasted. The percolating filter treating weak liquor also received 100 gallons (*i.e.*, 50 gallons of septic liquor plus 50 gallons of water), and the corresponding contact beds two fillings of this diluted liquor, equivalent to an *average* of 57·9 gallons per cube yard per day. The percolating filter treating weak liquor was thus receiving the same volume as the one treating strong liquor, but only half the organic impurity, and the same applied, approximately, to the two sets of contact beds.

Sampling.—Percolating Filters.—The samples in this experiment were drawn once a month, as a rule on different days of the week, the filter effluents being taken 20 to 30 minutes after the tank liquors.

Contact Beds.—These samples were also drawn once a month, the tank liquors when the beds were half full and the effluents at mid-flow. Each successive effluent, both "strong" and "weak," was taken a filling later than the one before it.

The septic tank liquors gave the following average analyses :—

Parts per 100,000.	Percolating Filters.		Contact Beds.	
	Strong Liquor.	Weak Liquor.	Strong Liquor.	Weak Liquor.
Ammoniacal Nitrogen	2·00 to 5·28 = 3·86 (5)	1·10 to 2·70 = 2·00 (4)	3·40 to 5·40 = 4·40 (2)	1·52 to 3·04 = 2·28 (2)
Albuminoid Nitrogen	0·37 to 0·86 = 0·64 (4)	0·22 to 0·49 = 0·34 (4)	0·42 to 0·88 = 0·65 (2)	0·27 to 0·43 = 0·35 (2)
Total Organic Nitrogen	0·98 to 2·27 = 1·45 (4)	0·57 to 0·99 = 0·85 (4)		0·70 to 0·85 = 0·78 (2)
Total Nitrogen (by Kjeldahl)	2·98 to 8·09 = 6·06 (8)	1·67 to 4·23 = 3·07 (8)	3·01 to 8·33 = 6·18 (7)	1·64 to 4·64 = 3·17 (8)
"Oxygen absorbed" at 27° C. *at once*	1·18 to 3·95 = 2·78 (7)	0·45 to 1·96 = 1·21 (7)	1·10 to 4·29 = 2·91 (7)	0·62 to 2·07 = 1·33 (7)
" " " *in 4 hours*	3·99 to 10·58 = 8·29 (8)	2·08 to 5·46 = 4·11 (8)	4·28 to 11·77 = 8·53 (8)	2·22 to 5·95 = 4·29 (8)
Chlorine (after deducting the chlorine of the town's water).	5·04 to 12·48 = 8·13 (8)	2·66 to 6·11 = 4·01 (8)	5·04 to 12·49 = 7·96 (8)	2·42 to 6·15 = 4·01 (8)
Solids in suspension	5·4 to 21·4 = 14·0 (8)	2·4 to 8·9 = 6·3 (8)	4·2 to 19·5 = 13·7 (8)	2·9 to 9·9 = 7·1 (8)
Volatile matter in these solids	3·8 to 16·2 = 9·7 (8)	1·9 to 7·1 = 4·2 (8)	3·0 to 14·5 = 9·3 (8)	2·5 to 8·1 = 5·0 (8)
Solids by Centrifuge (vols.)	21·7 to 103·4 = 59·8 (8)	10·8 to 50·0 = 28·7 (8)	21·7 to 125·7 = 67·4 (8)	10·8 to 61·6 = 35·3 (8)
Ratio of Solids in suspension to Centrifuge Solids	1 : 2·9 to 1 : 6·0 = 1 : 4·3 (8)	1 : 3·2 to 1 : 6·6 = 1 : 4·5 (8)	1 : 3·2 to 1 : 6·5 = 1 : 4·9 (8)	1 : 3·7 to 1 : 6·6 = 1 : 5·0 (8)

The filter effluents obtained gave the following average analyses, the figures in brackets indicating the number of estimations in each case :—

Parts per 100,000.	Percolating Filter Treating Strong Liquor.		Percolating Filter Treating Weak Liquor.		Contact Bed Treating Strong Liquor.			Contact Bed Treating Weak Liquor.		
	Original Effluent.	Effluent after Filtration through Paper.	Original Effluent.	Effluent after Filtration through Paper.	Primary Effluent.	Secondary Effluent.	Secondary Effluent after Filtration through Paper.	Primary Effluent.	Secondary Effluent.	Secondary Effluent after Filtration through Paper.
Ammoniacal Nitrogen	0·05 to 0·78 = 0·24 (8)	0·04 to 0·39 = 0·19 (6)	0·01 to 0·61 = 0·11 (8)	0·01 to 0·21 = 0·05 (6)	1·12 to 3·73 = 2·46 (7)	0·38 to 1·92 = 1·21 (8)	0·41 to 1·86 = 1·30 (6)	0·55 to 1·68 = 1·11 (7)	0·14 to 0·65 = 0·43 (8)	0·16 to 0·62 = 0·45 (6)
Albuminoid Nitrogen	0·07 to 0·20 = 0·12 (8)	0·07 to 0·14 = 0·11 (6)	0·04 to 0·11 = 0·07 (8)	0·04 to 0·07 = 0·06 (6)	0·23 to 0·72 = 0·46 (7)	0·15 to 0·56 = 0·31 (8)	0·10 to 0·22 = 0·14 (6)	0·13 to 0·30 = 0·20 (7)	0·07 to 0·22 = 0·13 (8)	0·06 to 0·12 = 0·08 (6)
Total Organic Nitrogen	0·37 to 0·84 = 0·55 (5)	0·20 to 0·47 = 0·36 (4)	0·08 to 0·59 = 0·42 (8)	0·21 to 0·44 = 0·35 (4)	0·58 to 1·18 = 0·78 (7)	0·57 to 0·71 = 0·64 (8)	0·24 to 0·85 = 0·44 (5)	0·30 to 0·67 = 0·45 (7)	0·11 to 0·47 = 0·27 (7)	0·17 to 0·36 = 0·28 (5)
Nitrous Nitrogen	0·00 to 0·16 = 0·04 (8)	0·00 to 0·10 = 0·03 (8)	0·00 to 0·03 = 0·01 (8)	0·00 to 0·03 = 0·01 (8)	0·00 to 0·15 = 0·07 (4)	0·10 to 1·05 = 0·33 (8)	0·02 to 0·18 = 0·06 (7)	0·00 to 0·22 = 0·07 (6)	0·00 to 0·28 = 0·08 (8)	0·00 to 0·02 = 0·00 (7)
Nitric Nitrogen	1·90 to 4·72 = 3·25 (8)	1·05 to 4·71 = 3·24 (5)	1·10 to 2·58 = 1·89 (8)	1·30 to 2·75 = 2·17 (6)	0·00 to 0·15 = 0·09 (4)	0·00 to 1·13 = 0·65 (8)	1·09 to 1·35 = 1·21 (6)	0·00 to 0·44 = 0·20 (6)	0·53 to 1·16 = 1·00 (8)	0·88 to 1·33 = 1·14 (5)
Total Nitrogen (by Kjeldahl)	2·35 to 5·69 = 3·99 (7)	3·48 to 5·56 = 4·68 (5)	1·43 to 3·08 = 2·44 (8)	2·08 to 2·95 = 2·67 (4)	2·00 to 4·91 = 3·50 (8)	2·00 to 3·38 = 2·84 (8)	2·53 to 3·50 = 3·22 (5)	1·29 to 2·36 = 1·86 (8)	1·28 to 2·29 = 1·80 (7)	1·86 to 2·00 = 1·93 (5)
"Oxygen absorbed" at 27° C. *at once*	0·06 to 0·97 = 0·45 (8)	0·08 to 0·48 = 0·31 (8)	0·02 to 0·31 = 0·20 (8)	0·11 to 0·29 = 0·21 (8)	0·84 to 1·90 = 1·25 (8)	0·36 to 1·88 = 0·97 (8)	0·19 to 0·49 = 0·32 (8)	0·31 to 0·84 = 0·56 (8)	0·05 to 0·75 = 0·39 (8)	0·12 to 0·28 = 0·19 (8)
,, ,, ,, *in 4 hours*	0·76 to 2·44 = 1·54 (8)	0·63 to 1·93 = 1·19 (8)	0·39 to 1·66 = 0·99 (8)	0·47 to 1·14 = 0·82 (7)	2·97 to 6·25 = 4·28 (8)	1·62 to 4·95 = 2·86 (8)	1·13 to 2·03 = 1·39 (8)	1·27 to 2·92 = 2·14 (8)	0·28 to 1·88 = 1·23 (8)	0·60 to 1·19 = 0·79 (8)
Incubator test (by smell)	7 + (7)	5 + (5)	6 + (6)	6 + (6)	8 − (8)	4 + , 3 − , 1 ? (8)	5 + (5)	2 + 6 − (8)	8 + , (8)	6 + , (6)
Chlorine (after deducting the Chlorine of the town's water).	4·58 to 12·87 = 7·81 (8)	5·18 to 12·88 = 8·74 (4)	2·57 to 6·66 = 4·18 (8)	2·58 to 6·67 = 4·70 (4)	4·65 to 13·97 = 8·15 (8)	4·45 to 15·48 = 8·37 (8)	5·73 to 15·46 = 9·31 (6)	2·59 to 6·76 = 4·12 (8)	2·44 to 7·55 = 4·30 (7)	2·75 to 7·53 = 4·64 (6)
Dissolved Oxygen taken up in 24 hours at 18° C.	0·15 to 0·45 = 0·25 (5)	0·00 to 0·07 = 0·03 (4)	0·09 to 0·18 = 0·12 (4)	0·04 to 0·11 = 0·06 (4)	1·06 to 4·03 = 2·68 (5)	0·30 to 0·73 = 0·52 (5)	0·06 to 0·16 = 0·10 (4)	0·22 to 4·03 = 1·46 (5)	0·12 to 0·39 = 0·25 (5)	0·07 to 0·21 = 0·13 (3)
Dissolved Oxygen taken up in 5 days at 18° C.		0·25 to 0·66 = 0·39 (3)		0·28 to 0·51 = 0·36 (3)		1·94 to 6·36 = 3·49 (3)	0·86 to 2·18 = 1·58 (3)		0·80 to 2·00 = 1·28 (3)	0·56 to 1·18 = 0·92 (3)
Solids in suspension	0·6 to 4·7 = 2·1 (7)		0·5 to 3·5 = 1·9 (7)		4·5 to 12·8 = 7·8 (8)	2·5 to 9·4 = 4·8 (8)		1·8 to 4·9 = 3·5 (7)	1·8 and 2·2 (2)	
Volatile matter in these solids	0·6 to 4·0 = 1·5 (7)		0·4 to 2·4 = 1·3 (7)		4·0 to 10·4 = 6·2 (8)	1·6 to 7·0 = 4·1 (8)		1·5 to 3·8 = 2·7 (7)	1·7 and 1·9 (2)	
Solids by Contrifuge (vols.)	10·4 to 52·2 = 25·0 (7)		10·8 to 40·8 = 22·7 (8)		19·0 to 100·1 = 43·1 (8)	20·0 to 87·1 = 50·8 (8)		12·6 to 35·2 = 28·3 (7)	6·6 to 27·2 = 17·7 (7)	
Ratio of solids in suspension to Centrifuge solids	1 : 7·2 to 1 : 17·4 = 1 : 13·5 (6)		1 : 8·8 to 1 : 21·6 = 1 : 14·4		1 : 1·8 to 1 : 10·4 = 1 : 6·0 (8)	1 : 8·0 to 1 : 15·7 = 1 : 10·6 (8)		1 : 5·3 to 1 : 13·5 = 1 : 8·3 (6)		

The figures for strength of liquors treated, and for suspended solids, therefore, were :—

	Percolating Filters.		Contact Beds.	
	Calculated Strength.	Suspended Solids.	Calculated Strength.	Suspended Solids.
Strong liquor - - -	81·2	14·0 (8)	83·3	13·7 (8)
Weak liquor - - -	40·5	6·3 (8)	42·2	7·1 (8)

The purification obtained was :—

	Units of Purification.	Percentage Purification.
Percolating filter treating strong liquor - - - -	8,440	104
Double contact beds treating strong liquor - - -	3,576	83
Percolating filter treating weak liquor - - - -	4,120	102
Double contact beds treating weak liquor - - - -	2,200	90

The quality of the various effluents may be given in tabular form, as follows :—

	Effluents from Strong Liquor.		Effluents from weak liquor.	
	Percolation.	Double Contact.	Percolation.	Double Contact.
	Parts of oxygen per 100,000 *parts of effluent.*			
Oxidizability of whole effluent, including solids and giving credit for nitrate -	*– 3·2	14·0	– 0·7	4·2
Oxidizability of effluent, without its suspended solids, and giving credit for nitrate - - - - - - - -	*– 6·2	5·8	– 3·3	0·2
Oxidizability of effluent, without solids and giving no credit for nitrate - - -	3·6	7·7	2·4	3·2

The quality of the effluents—*without their suspended solids*—as regards taking up of dissolved oxygen and incubation, is shown by the figures :—

	Effluents from Strong Liquor.		Effluents from Weak Liquor.	
	Percolation.	Double Contact.	Percolation.	Double Contact.
	Parts per 100,000.			
Dissolved oxygen taken up from water in 24 hours at about 18° C. - - - - -	0·03 (4)	0·12 (4)	0·07 (4)	0·10 (4)
Dissolved oxygen taken up from water in 5 or 6 days at 18° C. - - - - -	0·43 (3)	1·70 (3)	0·33 (4)	1·0 ap. (3)
†Incubation (by smell) - - - - -	All passed (8)	All passed (8)	All passed (8)	All passed (8)

The capacities of the contact beds (in gallons) were :—

	At beginning of Experiment, July 2nd, 1906.‡	At end of Experiment, February 18th, 1907.	Loss of capacity in Gallons.	Loss in percentage of original water capacity, when beds were new.
Primary bed treating strong liquor - -	735	640	95	8 per cent.
Secondary bed treating strong liquor -	1,030	970	60	6 ,,
Primary bed treating weak liquor - -	780	750	30	3 ,,
Secondary bed treating weak liquor - -	950	890	60	6 ,,

* The minus sign indicates that the oxygen present in the form of nitrate was, to the extent of the figure against which it is placed, more than sufficient to oxidize the ammonia and organic matter in the effluent.

† The incubation results were taken for granted in a good many cases, in order to economise the samples. There could be no doubt about this.

‡ With regard to the date on which the experiment began, *cf.* p. 52, note.

As already stated, the actual volumes of liquid treated per cube yard per 24 hours throughout Experiment II were :—

Percolating filter treating strong liquor - - - -	100 gallons.
Double contact beds treating strong liquor - - -	51·6 ,,
Percolating filter treating weak liquor - - - -	100 ,,
Double contact beds treating weak liquor - - -	57·9 ,,

The contact beds thus treated only about half as much liquor, in both cases, as the percolating filters.

The results may be summarized thus :—

Percolating Filters.

The filter treating 100 gallons of strong liquor did fully double as much work as that treating 100 gallons of weak liquor per cube yard, and gave on the whole a slightly better effluent, relatively to strength, though both effluents were very good, especially after elimination of the suspended solids. The filter treating strong liquor was therefore still working within the limits of efficiency, while that treating weak liquor was doing very much less work than it was capable of (*cf.* Experiment I) ; and nothing was gained, in purity of effluent, by diluting the septic liquor to half its strength and giving the weak liquor filter only half the work to do.

It will be noted that, in Experiment II, the percolating filter treating strong liquor (strength = 81·2) gave 8,440 units of purification per cube yard, as against 7,310 units in Experiment I (strength of liquor = 85·2). This increased working efficiency was no doubt mainly due to the fact that from the very commencement of the second experiment the filter was thoroughly mature.

Incidentally, the above results show that a percolating filter of fairly coarse material (say 2 inches to 3 inches in diameter, and 6 feet deep), can treat a septic tank liquor of over average strength (strength 80 to 85), and containing 14 parts of suspended solids per 100,000, at the rate of 100 gallons per cube yard per day, giving 8,000 to 9,000 units of purification and producing a good effluent (apart from suspended solids).

Contact Beds.

The pair of contact beds treating 57·9 gallons per cube yard of weak liquor gave *more than half* the purification which was effected by the beds treating 51·6 gallons of strong liquor (even if we allow for difference in volume treated, because of the difference in capacity), and also a better percentage purification. The beds treating strong liquor showed less absolute purification than in Experiment I (3,576 units, as against 5,011), though almost the same percentage purification ; if we allow for the difference in volume treated in the two experiments (72·2 gallons per cube yard in I, as against 51·6 gallons in II), the relative purification effected was as nearly as possible the same in both cases. *The efficiency of these contact beds, in proportion to their capacity per cube yard, therefore remained the same in both experiments.*

The beds treating weak liquor also show less (than half the) absolute purification effected in Experiment I (2,200 units, as against 5,654), though practically the same percentage purification. Allowing, again, for the difference in volume treated in the two experiments (148·8 gallons per cube yard in I and 57·9 gallons in II), the relative purification effected was again as nearly as possible the same. *The efficiency of the beds treating weak liquor, therefore, also remained the same, or practically the same, in both experiments.*

The secondary contact bed effluent from the weak liquor was—apart from its solids—of very good quality, that from the strong liquor only moderate. The mean diminution in capacity of the beds treating strong liquor was 7 per cent. and of those treating weak liquor 4·5 per cent. of the original capacity.* It is noteworthy that the secondary bed treating weak liquor lost capacity more than the primary bed treating weak liquor, though in neither case was the loss great. It is difficult to explain this, as the primary effluent from the strong liquor contained 8·3 † parts of suspended solids, while that from the weak liquor had only 3·5† parts. The suspended solids in the weak secondary effluent were *about* 2 parts (as judged mainly by the centrifuge figures), and in the strong 4 parts.

With regard to the relative oxidation in the different beds, the primary bed treating strong liquor gave 2,472 units of purification, as against 1,104 given by the secondary bed;

* Equivalent to about 12 per cent. and 7 per cent., respectively, on a year's working.

† These are average figures from seven analyses in each case.

the primary bed treating weak liquor gave 1,512, as against 688 by the secondary. Roughly speaking, therefore, fully two-thirds of the impurity in the tank liquor was oxidized—or, at all events, removed—by the primary bed in both cases.

The *relative* purification by the contact beds in Experiment II—in which approximately equal *volumes* were taken—was thus in favour of the beds treating weak liquor. This is in agreement with the results obtained in Experiment I, while it also emphasizes the essential difference between contact beds and percolating filters, viz., that the former can only have a relatively limited air supply, as compared with the latter. The reduction of the organic matter treated by the weak liquor contact beds in Experiment II, to half that treated in Experiment I, did not result in the production of a better effluent (excepting that the suspended solids were rather less in II), both being good.

The foregoing Experiments I *and* II *go to show that primary contact beds of medium to coarse material and secondary beds of fine material, each* 3 *feet deep, can treat a septic tank liquor of over average strength* (*strength* = 80 *to* 85), *and containing* 14 *to* 15 *parts of suspended solids, at an* average *rate of about* 70 *gallons per cube yard per* 24 *hours for one year, giving* 5,000 *units of purification, or at an average rate of* 60 *gallons per cube yard for two years, giving* 4,500 *units of purification, and producing an effluent of fair quality, apart from suspended solids. If the liquor treated has a strength of only* 40 *to* 43, *with about* 7 *parts of suspended solids, such beds can treat an average of* 150 *gallons per cube yard per day for* 14 *months, giving* 5,800 *units of purification and producing a good effluent.*

Experiment III.

In this experiment, which lasted from April 8th to June 7th, 1907, the percolating filter treating strong liquor received 125 gallons per cube yard per day and that receiving weak liquor 250 gallons. It was thus similar to Experiment I, but with an increased dose in the case of both filters, the object being to see how much the filters could actually treat with efficiency. Owing to the wet season, however, the strength of the liquors in this experiment was less than in Experiments I and II, thus :—

	Calculated Strength.	Suspended Solids.
Strong liquor - - - - - - - - - -	73·2	20·1
Weak liquor - - - - - - - - - -	40·7	10·3

The suspended solids in the filter effluents were rather high, on account of the " spring out-flush." *

Samples were drawn every fifteen days, as before, an hour later each time, and the effluents from 20 to 30 minutes after the tank liquors.

The septic tank liquors gave the following average analyses :—

Parts per 100,000.	Strong Liquor.	Weak Liquor.
Ammoniacal Nitrogen - - - -	2·48 (1)	1·38 (1)
Albuminoid Nitrogen - - - -	0·52 (1)	0·27 (1)
Total organic Nitrogen - - - -		
Total Nitrogen - - - - -	2·32 to 8·58 = 5·12 (5)	1·06 to 4·29 = 2·64 (5)
" Oxygen absorbed " at 27° *at once* -	1·21 to 4·14 = 2·44 (5)	0·57 to 2·18 = 1·35 (5)
,, ,, ,, *in* 4 *hours* -	4·94 to 14·08 = 8·45 (5)	2·34 to 7·82 = 4·68 (5)
Chlorine (after deducting the Chlorine of the town's water).†	3·23 to 8·90 = 5·87 (5)	1·46 to 4·51 = 3·02 (5)
Solids in suspension - - - -	14·1 to 29·8 = 20·1 (5)	6·0 to 15·1 = 10·3 (5)
Volatile matter in these solids - -	9·5 to 22·0 = 14·1 (5)	4·1 to 11·1 = 7·3 (5)
Solids by Centrifuge (vols.) - - -	63·0 to 111·2 = 87·8 (3)	37·1 to 58·0 = 47·0 (3)
Ratio of Solids in suspension to Centrifuge Solids.	1 : 3·7 to 1 : 5·9 = 1 : 4·45 (3)	1 : 3·8 to 1 : 7·7 = 1 : 4·79 (3)

* As is now well known, large quantities of suspended solids usually come out in the effluent from a percolating filter of coarse material in the late spring, with the advent of the warmer weather. This appears to be due to the development of worms, larvæ, etc., in the interior of the filter at this time. The same thing has been observed, though in lesser degree, in the case of percolating filters of fine material and contact beds.

† The Chlorine of the town's water is here taken at 1·3 (*cf.* Note 1, p. 53). If anything, this may be a little too high.

The filter effluents obtained gave the following average analyses, the figures in brackets indicating the number of estimations in each case :—

Parts per 100,000.	Percolating Filter Treating Strong Liquor.		Percolating Filter Treating Weak Liquor.	
	Original Effluent.	Effluent after Filtration through Paper.	Original Effluent.	Effluent after Filtration through Paper.
Ammoniacal Nitrogen	0·01 to 1·18 = 0·37 (5)	0·01 to 0·27 = 0·12 (3)	0·02 to 1·02 = 0·28 (5)	0·02 to 0·12 = 0·08 (3)
Albuminoid Nitrogen	0·17 to 0·46 = 0·27 (5)	0·07 to 0·15 = 0·10 (3)	0·08 to 0·21 = 0·16 (5)	0·05 to 0·10 = 0·07 (3)
Total organic Nitrogen	0·35 to 1·14 = 0·70 (5)	0·18 to 0·22 = 0·20 (3)	0·25 to 0·41 = 0·31 (5)	0·07 and 0·21 (2)
Nitrous Nitrogen	0·00 to 0·17 = 0·07 (5)	0·00 to 0·08 = 0·04 (5)	0·00 to 0·08 = 0·04 (5)	0·00 to 0·05 = 0·02 (5)
Nitric Nitrogen	2·00 to 2·97 = 2·32 (5)	2·00 to 2·82 = 2·35 (3)	1·00 to 2·00 = 1·36 (5)	1·10 to 1·53 = 1·22 (5)
Total Nitrogen	2·55 to 4·42 = 3·45 (5)	2·19 to 3·37 = 2·67 (3)	1·36 to 2·60 = 2·00 (5)	1·29 and 1·85 (2)
"Oxygen absorbed" at 27° C. *at once*	0·28 to 1·41 = 0·85 (5)	0·09 to 0·57 = 0·35 (5)	0·21 to 0·68 = 0·43 (5)	0·08 to 0·40 = 0·21 (5)
" " " *in 4 hours*	1·47 to 5·37 = 3·61 (5)	0·63 to 2·08 = 1·31 (5)	0·86 to 3·10 = 1·94 (5)	0·38 to 1·50 = 0·95 (5)
Incubator test (by smell)	5 + (5)	5 + (5)	5 + (5)	5 + (5)
Chlorine (after deducting the Chlorine of the town's water)	3·17 to 8·90 = 5·98 (5)	3·24 to 8·90 = 5·99 (5)	1·54 to 4·61 = 3·08 (5)*	1·52 to 4·61 = 3·06 (5)
Oxygen in solution	0·00 to 0·71 = 0·29 (5)	0·31 to 0·93 = 0·62 (5)	0·08 to 0·81 = 0·41 (5)	0·47 to 0·96 = 0·69 (5)
Dissolved Oxygen taken up in 5 days at 18° C.	0·79 to 7·89 = 3·26 (4)	0·07 to 1·19 = 0·61 (5)	0·77 to 2·99 = 1·81 (5)	0·42 to 1·59 = 0·80 (5)
Solids in suspension	3·8 to 12·6 = 8·5 (5)	—	1·7 to 6·4 = 3·0 (5)	—
Volatile matter in these solids	2·5 to 8·7 = 5·5 (5)	—	1·5 to 4·4 = 2·6 (5)	—
Solids by Centrifuge (vols.)	46·8 to 148·2 = 91·4 (3)	—	20·0 to 58·0 = 44·6 (5)	—
Ratio of Solids in suspension to Centrifuge Solids	1 : 11·0 to 1 : 12·4 = 1 : 11·7 (3)	—	1 : 11·6 to 1 : 20·0 = 1 : 15·8	—

* One interpolation, from the corresponding paper-filtered effluent.

The purification obtained was :—

	Units of Purification.	Percentage Purification.
Percolating filter treating strong liquor - - - - - -	8,050	88
Percolating filter treating weak liquor - - - - - -	9,225	91

The quality of the two effluents is shown by the figures :—

	Effluent from Strong Liquor.	Effluent from Weak Liquor.
	Parts of oxygen per 100,000 parts of effluent.	
Oxidizability of whole effluent, including solids and giving credit for nitrate - - - - - - - - - - -	8·8	3·8
Oxidizability of effluent, without its suspended solids and giving credit for nitrate - - - - - - - - -	– 2·2	– 1·4
Oxidizability of effluent, without solids and giving no credit for nitrate - - - - - - - - - -	4·8	2·7

The quality of the effluents—*without their suspended solids*, as regards taking up of dissolved oxygen and incubation—is shown by the figures :—

	Effluent from Strong Liquor.	Effluent from Weak Liquor.
Dissolved oxygen taken up from water in 5 days at 18° C. - -	0·62 (5)	0·84 (5)
Incubation (by smell) - - - - - - - - - -	All passed (5)	All passed (5)

Both effluents were therefore very good, and, apart from their suspended solids, there was practically nothing to choose between them. It will be noted that the filter treating weak liquor was receiving a liquor proportionately rather stronger than the other (calculated strength = 40·7, as against 73·2 for the strong liquor).

Owing to the strong liquor being less concentrated in this experiment than in the two preceding ones, the actual work done on the filter treating strong liquor was only 8,050 units of purification per cube yard per 24 hours, but in the case of the filter treating weak liquor it was 9,225 units.

This experiment, therefore, supplements Experiments I *and* II *in showing that a percolating filter of coarse material,* 6 *feet deep, can treat a septic tank liquor of above average strength* (*strength* 73), *and containing about* 20 *parts of suspended solids, at the rate of* 125 *gallons per cube yard per* 24 *hours, or one of half that strength, with* 10 *parts of suspended solids, at the rate of* 250 *gallons, giving in both cases* 8,000 *to* 9,000 *units of purification, and producing a good well-oxidized effluent* (*apart from suspended solids*).

Experiment IV.

In this experiment, which lasted from June 10th to October 26th, 1907, the percolating filter treating strong liquor received 200 gallons and that receiving weak liquor 400 gallons per cube yard per day. It was thus similar to Experiments I and III, but with a further increased dose in the case of both filters. Samples were drawn every fifteen days, as before, an hour later each time, and the effluents about 20 minutes after the tank liquors. The calculated strengths of the tank liquors in this experiment were almost the same as in the preceding one, but the suspended solids were less in amount, thus :—

	Calculated Strength.	Suspended Solids.
Strong tank liquor - - - - - - - -	74·1	13·5
Weak tank liquor - - - - - - - -	39·6	6·3

The weak liquor filter was again treating a liquor which was *rather more* than half as strong as the other.

The septic tank liquors gave the following average analyses :—

Parts per 100,000.	Strong Liquor.	Weak Liquor.
Ammoniacal Nitrogen - - - -	2·72 to 6·40 = 4·59 (8)	1·29 to 3·02 = 2·22 (8)
Albuminoid Nitrogen - - - -	0·48 to 0·87 = 0·60 (8)	0·21 to 0·49 = 0·35 (8)
Total organic Nitrogen - - - -	0·69 to 1·34 = 0·99 (7)	0·42 to 1·94 = 0·81 (8)*
Total Nitrogen - - - - -	3·49 to 6·96 = 5·34 (9)	1·78 to 3·93 = 2·77 (9)*
"Oxygen absorbed" at 27° C. *at once* -	1·47 to 3·93 = 2·63 (9)	0·59 to 1·87 = 1·23 (9)
" " " *in 4 hours*	5·15 to 11·25 = 7·70 (9)	3·24 to 6·05 = 4·17 (9)
Chlorine (after deducting the Chlorine of town's water).†	4·64 to 9·60 = 6·83 (9)	2·20 to 5·03 = 3·49 (9)
Solids in suspension - - - -	9·6 to 20·1 = 13·5 (9)	3·6 to 9·2 = 6·3 (9)
Volatile matter in these solids - -	6·7 to 15·3 = 9·6 (9)	2·2 to 6·4 = 4·4 (9)
Solids by Centrifuge (vols.) - - -	52·0 to 89·1 = 65·1 (9)	29·9 to 46·5 = 38·0 (9)
Ratio of Solids in suspension to Centrifuge Solids.	1 : 3·2 to 1 : 6·2 = 1 : 4·8 (9)	1 : 4·1 to 1 : 11·1 = 1 : 6·8 (9)

* Including 2 interpolations.

† The Chlorine of the town's water is again taken at 1·3 for Experiment IV. If anything, this may be a little too high. Only three estimations of Chlorine in the water were made, towards the end of this experiment, and these gave the figures 1·18, 1·18 and 1·17.

The filter effluents obtained gave the following average analyses, the figures in brackets indicating the number of estimations in each case :—

Parts per 100,000.	Percolating Filter Treating Strong Liquor.		Percolating Filter Treating Weak Liquor.	
	Original Effluent.	Effluent after Filtration through Paper.	Original Effluent.	Effluent after Filtration through Paper.
Ammoniacal Nitrogen	0·13 to 0·86 = 0·58 (9)	0·12 to 0·86 = 0·57 (9)	0·01 to 0·91 = 0·28 (9)	0·01 to 0·92 = 0·29 (9)
Albuminoid Nitrogen	0·13 to 0·27 = 0·18 (9)	0·07 to 0·14 = 0·12 (9)	0·07 to 0·18 = 0·12 (9)	0·05 to 0·13 = 0·06 (9)
Total organic Nitrogen	0·26 to 0·57 = 0·41 (8)	0·18 to 0·64 = 0·31 (7)	0·12 to 0·42 = 0·24 (9)	0·09 to 0·65 = 0·24 (6)
Nitrous Nitrogen	0·00 to 0·15 = 0·09 (9)	0·00 to 0·10 = 0·06 (9)	0·00 to 0·20 = 0·06 (9)	0·00 to 0·06 = 0·03 (9)
Nitric Nitrogen	2·23 to 3·44 = 2·74 (9)	2·25 to 3·43 = 2·78 (9)	1·46 to 2·60 = 1·81 (9)	0·40 to 2·23 = 1·61 (9)
Total Nitrogen	2·81 to 4·59 = 3·78 (9)	2·81 to 4·57 = 3·66 (9)	1·59 to 2·93 = 2·23 (8)	1·50 to 3·22 = 2·23 (8)
" Oxygen absorbed " at 27° C. *at once*	0·38 to 0·86 = 0·64 (9)	0·23 to 0·59 = 0·42 (9)	0·16 to 0·76 = 0·41 (9)	0·18 to 0·51 = 0·26 (9)
,, ,, ,, *in 4 hours*	1·69 to 3·17 = 2·33 (9)	0·96 to 1·98 = 1·43 (9)	0·54 to 2·61 = 1·55 (9)	0·51 to 1·65 = 0·94 (9)
Incubator test (by smell)	9 + (9)	9 + (9)	9 + (9)	9 + (9)
Oxygen in solution	0·00 to 0·58 = 0·29 (9)	0·43 to 0·81 = 0·65 (9)	0·00 to 0·70 = 0·37 (9)	0·44 to 0·83 = 0·68 (9)
Dissolved Oxygen taken up in 48 hours at 18° C.	0·31 to 1·26 = 0·67 (8)	0·09 to 0·35 = 0·19 (8)	0·00 to 1·47 = 0·61 (8)	0·00 to 0·40 = 0·21 (8)
Dissolved Oxygen taken up in 5 days at 18° C.	1·47 to 3·61 = 2·56 (8)	0·19 to 1·17 = 0·59 (9)	0·00 to 3·30 = 1·66 (8)	0·00 to 1·04 = 0·48 (9)
Chlorine (after deducting the Chlorine of the town's water)	4·73 to 9·36 = *6·87 (9)	4·75 to 9·33 = 6·85(9)	2·12 to 4·93 = *3·50 (9)	2.12 to 4·84 = 3·47 (9)
Solids in suspension	3·0 to 7·7 = 5·1 (8)	—	1·8 to 4·5 = 3·2 (9)	—
Volatile matter in these solids	2·0 to 4·9 = 3·6 (8)	—	1·5 to 3·6 = 2·4 (9)	—
Solids by Centrifuge (vols.)	33·0 to 72·2 = 53·7 (9)	—	35·0 to 55·7 = 44·3 (9)	—
Ratio of Solids in suspension to Centrifuge Solids	1 : 8·61 to 1 : 14·75 = 1 : 11·1 (9)	—	1 : 9·7 to 1 : 19·4 = 1 : 13·8 (9)	—

* One interpolation.

The purification obtained was :—

	Units of Purification.	Percentage Purification.
Percolating filter treating strong liquor - - -	14,300	96
Percolating filter treating weak liquor - - -	15,160	96

The quality of the two effluents is shown by the figures :—

	Effluent from Strong Tank Liquor.	Effluent from Weak Tank Liquor.
	Parts of oxygen per 100,000 *parts of effluent.*	
Oxidizability of whole effluent, including solids and giving credit for nitrate.	2·6	1·7
Oxidizability of effluent, without its suspended solids and giving credit for nitrate.	—3·8	—3·1
Oxidizability of effluent, without solids and giving no credit for nitrate.	4·4	2·3

The quality of the effluents—*without their suspended solids,* as regards taking up of dissolved oxygen and incubation—is shown by the following figures :—

	Effluent from Strong Tank Liquor.	Effluent from Weak Tank Liquor.
Dissolved oxygen taken up from water in 5 days at 18° C.	0·56 (9)	0·49 (9)
Incubation (by smell) - - - - - - -	All passed (9)	All passed (9)

Here again both effluents were well oxidized and good, and there was little to choose between them. If anything, they were rather better oxidized than the corresponding effluents in Experiment III (notwithstanding the lesser volumes treated in that case), as judged by the dissolved oxygen taken up by the paper-filtered effluents in five days. This was probably due to the fact that more of the warm summer months were included in Experiment IV, and also to the spring out-flush of solids having taken place during Experiment III.

The work done on the filter treating strong liquor was 14,300 units, and on the filter treating weak liquor 15,160 units.

Experiment V.

In this final experiment, which lasted from October 28th, 1907, to June 18th, 1908, the percolating filter treating strong liquor received 250 gallons and that receiving weak liquor 500 gallons per cube yard per day. As before, samples were drawn every fifteen days, an hour later each time, and the effluents 20 minutes after the tank liquors. The calculated strengths of the liquors treated were a little less than in Experiment IV, though suspended solids were present in rather larger amount, thus :—

	Calculated Strength.	Suspended Solids.
Strong liquor - - - - - - - -	69·4	14·4
Weak liquor - - - - - - - -	37·0	7·4

As before, the weak liquor filter was treating a liquor which was fully half as strong as the other.

The septic tank liquors gave the following average analyses :—

Parts per 100,000.	Strong Liquor.	Weak Liquor.
Ammoniacal Nitrogen - - - -	0·99 to 5·44 = 3·68 (13)	0·90 to 2·86 = 1·99 (12)
Albuminoid Nitrogen - - - -	0·22 to 1·03 = 0·61 (13)	0·21 to 0·53 = 0·36 (12)
Total organic Nitrogen - - - -	0·53 to 2·49 = 1·25 (13)	0·37 to 0·95 = 0·76 (12)
Total Nitrogen - - - - -	1·84 to 7·28 = 4·93 (13)	1·28 to 3·81 = 2·75 (12)
"Oxygen absorbed" at 27° C. *at once* -	0·87 to 2·96 = 1·93 (13)	0·42 to 1·53 = 0·98 (12)
,, ,, ,, *in 4 hours*	3·03 to 12·79 = 7·26 (13)	1·78 to 6·25 = 4·08 (12)
Chlorine (after deducting the Chlorine of the town's water).	2·21 to 10·37 = 6·36 (13)	1·95 to 5·48 = 3·45 (12)
Solids in suspension - - - - -	9·2 to 22·1 = 14·4 (13)	4·9 to 10·6 = 7·6 (12)
Volatile matter in these solids - -	5·6 to 16·1 = 10·1 (13)	3·3 to 7·6 = 5·4 (12)
Solids by Centrifuge (vols.) - - -	38·0 to 99·1 = 61·3 (13)	11·8 to 51·1 = 31·7 (12)
Ratio of Solids in suspension to Centrifuge Solids.	1 : 3·4 to 1 : 5·6 = 1 : 4·3 (13)	1 : 2·4 to 1 : 4·8 = 1 : 4·1 (12)

The effluents gave the following average analyses :—

Parts per 100,000.	Percolating Filter Treating Strong Liquor.		Percolating Filter Treating Weak Liquor.	
	Original Effluent.	Effluent after Filtration through Paper.	Original Effluent.	Effluent after Filtration through Paper.
Ammoniacal Nitrogen	0·10 to 3·70 = 1·79 (13)	0·08 to 3·70 = 1·80 (13)	0·02 to 1·87 = 0·81 (13)	0·03 to 1·85 = 0·80 (13)
Albuminoid Nitrogen	0·11 to 0·68 = 0·36 (13)	0·05 to 0·40 = 0·22 (13)	0·05 to 0·33 = 0·16 (13)	0·07 to 0·16 = 0·11 (13)
Total organic Nitrogen	0·27 to 1·19 = 0·64 (10)	0·24 to 0·52 = 0·36 (8)	0·07 to 0·48 = 0·34 (8)	0·08 to 0·50 = 0·21 (10)
Nitrous Nitrogen	0·03 to 0·33 = 0·12 (13)	0·00 to 0·10 = 0·04 (13)	0·00 to 0·08 = 0·03 (13)	0·00 to 0·06 = 0·01 (13)
Nitric Nitrogen	0·26 to 2·51 = 1·23 (13)	0·53 to 1·72 = 1·31 (12)	0·33 to 1·36 = 0·94 (13)	0·46 to 1·38 = 0·91 (13)
Total Nitrogen	1·79 to 5·04 = 3·80 (11)	1·87 to 4·58 = 3·49 (12)	1·39 to 2·69 = 2·02 (11)	1·00 to 2·65 = 1·88 (12)
"Oxygen absorbed" at 27° C. *at once*	0·16 to 1·44 = 0·89 (13)	0·00 to 0·63 = 0·36 (13)	— 0·09 to 0·81 = 0·38 (13)	0·07 to 0·39 = 0·22 (13)
,, ,, ,, *in 4 hours*	1·41 to 6·14 = 3·89 (13)	0·67 to 2·85 = 1·70 (13)	0·67 to 3·11 = 1·76 (13)	0·47 to 1·62 = 0·97 (13)
Incubator test (by smell)	8 + ; 5 — ; (13)	11 + ; 2 — ; (13)	10 + ; 3 — ; (13)	13 + ; (13)
Oxygen in solution	0·00 to 0·74 = 0·19 (13)	0·31 to 0·92 = 0·65 (13)	0·07 to 0·82 = 0·43 (13)	0·60 to 0·94 = 0·79 (13)
Chlorine (after deducting the Chlorine of the town's water)	1·95 to 9·75 = 6·28 (13)	2·07 to 9·55 = 6·24 (13)	0·95 to 5·05 = 3·18 (13)	1·09 to 4·94 = 3·18 (13)
Dissolved Oxygen taken up in 48 hours at 18° C.	0·74 to 6·6 = 2·26 * (13)	0·30 to 2·65 = 0·89 (13)	0·21 to 2·46 = 0·97 (13)	0·07 to 2·02 = 0·57 (13)
Dissolved Oxygen taken up in 5 days at 18° C.	1·36 to 17·2 + x = 6·68 † (13)	0·65 to 4·6 + x = 2·31 ‡ (13)	0·80 to 6·91 = 2·82 (13)	0·40 to 2·47 = 1·16 (13)
Solids in suspension	3·3 to 16·4 = 9·5 (13)	—	2·2 to 6·5 = 3·9 (13)	—
Volatile matter in these solids	2·6 to 11·0 = 6·3 (13)	—	1·8 to 4·7 = 2·8 (13)	—
Solids by Centrifuge (Vols.)	42·4 to 174·0 = 92·8 (12)	—	18·0 to 62·2 = 44·1 (13)	—
Ratio of Solids in suspension to Centrifuge Solids	1 : 6·2 to 1 : 15·7 = 1 : 9·9 (12)	—	1 : 4·0 to 1 : 21·4 = 1 : 11·3 (13)	—

* The oxygen was exhausted in one instance. † Oxygen exhausted in three instances. ‡ Oxygen exhausted in one case.

The purification obtained was :—

—	Units of Purification.	Percentage Purification.
Percolating filter treating strong liquor - - -	12,425	72
Percolating filter treating weak liquor - - -	14,600	79

The quality of the effluents is shown by the figures :—

—	Effluent from Strong Tank Liquor.	Effluent from Weak Tank Liquor.
	Parts of Oxygen per 100,000 parts of Effluent.	
Oxidizability of whole effluent, including solids and giving credit for nitrate.	19·7	7·8
Oxidizability of effluent, without its suspended solids and giving credit for nitrate.	7·1	2·2
Oxidizability of effluent, without solids and giving no credit for nitrate.	10·8	5·0

The quality of the effluents—*without their suspended solids*, as regards taking up of dissolved oxygen and incubation—is shown by the following figures :—

—	Effluent from Strong Tank Liquor.	Effluent from Weak Tank Liquor.
Dissolved oxygen taken up from water in 5 days at 18° C.	2·31 (13)	1·16 (13)
Incubation (by smell) - - - - - - -	{ 11 passed 2 failed (13)	All passed (13)

The effluents in Experiment V thus show a marked falling off in quality, as compared with those in Experiments IV and III. Leaving suspended solids out of account, the weak liquor effluent is distinctly better, relatively, than the effluent from the strong liquor. It will be noted, however, that even in this last experiment, after filtration through paper, only two of the thirteen strong liquor effluents failed upon incubation, while all thirteen weak liquor effluents passed. The latter effluents might be described as fairly good, but the strong liquor effluents as rather poor. The spring out-flush of solids again took place during this experiment, which—it must be borne in mind—was carried out for the most part in the coldest months of the year.

The work done on the filter treating strong liquor was 12,425 units, and on the filter treating weak liquor 14,600 units.

It was evident, from the appearance of the filters during the progress of Experiment V, that they were being overtaxed, especially the filter treating strong liquor. The concrete at the base of the filters gradually became blackened and covered, more or less, with grey fungus, while at times the effluents smelt slightly of sewage.

Summary.

The foregoing experiments go to show that percolating filters of coarse material, 6 feet deep, can treat a strong septic tank liquor (strength 73 to 85) at a rate of 100 to 125 gallons per cube yard per day, or a liquor of half this strength at a rate of 200 to 250 gallons, giving from 8,000 to 9,000 units of purification and producing at the same time a good effluent (apart from suspended solids).

Under favourable conditions of summer weather, a strong septic tank liquor (strength 74) can be treated at a rate up to 200 gallons per cube yard per day, or a liquor of half this strength at a rate up to 400 gallons, with from 14,000 to 15,000 units of purification and the production of a good effluent. This is probably about the maximum work which

can be expected from percolating filters of coarse material treating ordinary septic tank liquor at a regular rate of flow.

As regards the question whether it is easier to treat upon percolating filters of coarse material one volume of strong septic liquor or two volumes of weak, the organic impurity being the same in both cases, the experiments show that there is little difference either in the actual work done by the filters or in the quality of the effluents, at rates of working up to 200 and 400 gallons, respectively, per cube yard per day. If any distinction is to be drawn, the advantage lies with the filter treating the weaker liquor, no doubt because the natural aeration of the extra volume of liquid rather more than counterbalances the quicker rate of flow through the filter.

Double contact beds will, during their first year of work, at the rate of two fillings per day, treat about 75 gallons of strong or 150 gallons of weak tank liquor (strengths about 86 and 43, respectively), per cube yard per day, and give 5,000 to 6,000 units of purification for the first year, with the production of a fair to good, non-putrescible effluent (apart from suspended solids). Their working power will, however, gradually fall off so long as the beds continue to lose capacity. Here, again, it is rather easier to treat two volumes of weak than one of strong liquor.

It is clear from these experiments that, other things being equal, a greater purification per cube yard, as measured by the actual *amount* of oxygen used up, is effected when the final product is an *imperfectly* oxidized effluent. The indications are that, unit for unit, the first or carbon stage of the oxidation is, under the conditions of filtration, easier, or at least quicker, and therefore presumably requires less expenditure of energy than the second or nitrification stage.

The filters on which the foregoing experiments were carried out for the Commission were constructed by Mr. W. J. Newton, Borough Surveyor, Accrington, while Mr. J. Boothman, Chemist at the Works, had them under his charge. This involved great care and attention on Mr. Boothman's part over a long period of time. We desire to express our cordial thanks to both of these gentlemen for the help thus given.

GEORGE McGOWAN.
COLIN C. FRYE.

July, 1909.

EXPERIMENT ON THE WASHING OUT OF A PERCOLATING FILTER WITH WATER,

By Dr. McGowan, Mr. Frye, and Mr. A. F. Girvan, B.Sc.

Sir William Power suggested that it might be of practical interest to study the effect of turning water on to a percolating filter which had been treating sewage liquor, and an opportunity occurred for doing this in 1908 on the Accrington experimental filter B.W.

A somewhat similar experiment had been tried by Colonel Harding and Mr. W. H. Harrison at Leeds, about the year 1900, with the triplicate percolating filter which was then being tried.

The Accrington filter B.W. is 6 feet high and 10 feet in diameter; it is filled with coke about 2in. to 3in. in size and is fed by a rotating sprinkler. For a number of years it had been continuously treating diluted septic tank liquor at different rates,* the rate for the eight months immediately preceding this water experiment being the extremely high one of 500 gallons per cube yard per 24 hours. Notwithstanding this, a well-nitrated effluent was still being produced and the coke of the filter continued in good condition.

On June 19th, 1908, at 7 a.m. the flow of septic liquor on to the filter was stopped, and town's water was substituted at the rate of 100 gallons per cube yard per 24 hours. A sample of filter effluent was drawn for analysis before the change was made, and then hourly samples were taken for the next 24 hours. After that daily samples were drawn until August 12th, the effluents analysed from June 22nd being a mixture of two or three daily samples. From August 19th, single samples were drawn once a week until September 30th, when the experiment ended. A few samples of the town's water were also examined at different times.

The first part of the experiment, from June 19th to 24th, was carried out by Mr. A. F. Girvan, with Mr. Boothman's help.

The main objects of the experiment were:-

(1) To see how long nitrate continued in appreciable quantity in the effluent, and thus to judge of the rate of oxidation of the accumulated nitrogenous matter in the filter.

(2) To note the rate at which solids continued to be washed out.

(3) To determine the point at which the septic tank liquor in the filter was entirely displaced by water, as judged by the chlorine figures of the samples, and to deduce from this the "average time of contact" of the liquid under treatment.

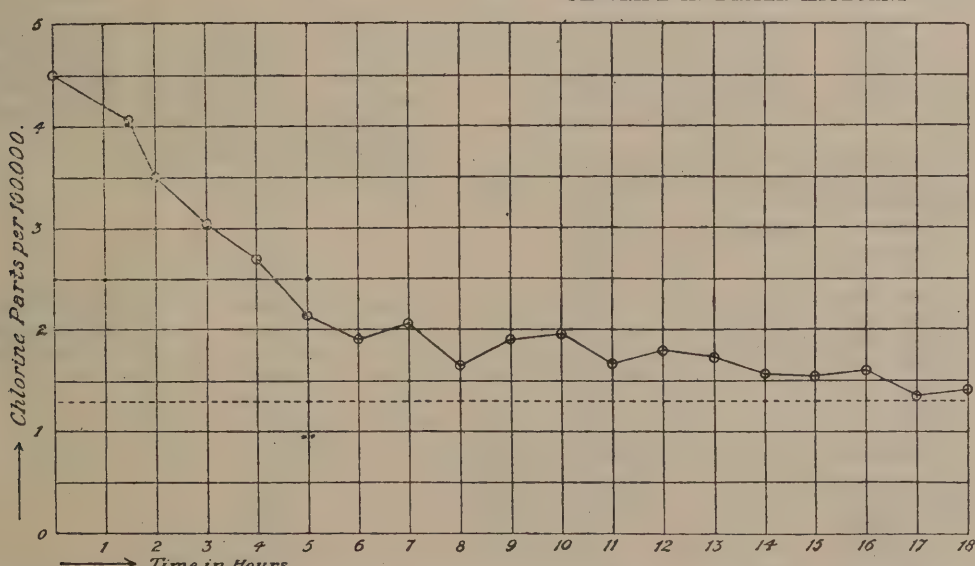
It will be convenient to deal first with the third object—

Table G.

Date.	Hour.	Chlorine (parts per 100,000). Water going on to Filter.	Filter Effluent.
1908.			
June 19 † - -	7. 0 a.m.	—	4·50
" - -	8.30 "	1·13	4·05
" - -	9. 0 "	—	3·50
" - -	10. 0 "	—	3·06
" - -	11. 0 "	—	2·70
" - -	12. 0 noon	—	2·12
" - -	1. 0 p.m.	—	1·90
" - -	2. 0 "	—	2·05
" - -	3. 0 "	—	1·65
" - -	4. 0 "	—	1·89
" - -	5. 0 "	—	1·97
" - -	6. 0 "	—	1·67
" - -	7. 0 "	—	1·80
" - -	8. 0 "	—	1·73
" - -	9. 0 "	—	1·57
" - -	10. 0 "	—	1·55
" - -	11. 0 "	—	1·60
" - -	12. 0 night	—	1·37
June 20 - -	1. 0 a.m.	—	1·42
" - -	2. 0 "	—	1·42
" - -	3. 0 "	—	1·40
" - -	4. 0 "	—	1·41
" - -	5. 0 "	—	1·47
" - -	6. 0 "	—	1·42
" - -	7. 0 "	—	1·40
" - -	1. 0 p.m.	1·29	1·40
" - -	7. 0 "	1·31	1·45
June 21 - -	7. 0 a.m.	1·28	1·40
June 22 - -	7. 0 "	1·27	1·26
June 23 - -	average of 4 samples of effluent	1·30	1·40
June 24 - -	average of 4 samples	1·23	1·40

Table G, with the accompanying curve, gives in detail the chlorine figures from the morning of June 19th to June 24th, while Table B.W. (p. 74) gives the remaining figures of analysis of the samples up to the end of the experiment on September 30th.

Chlorine in Town's Water ---------------
Chlorine in Filter Effluent ————————



From Table G and the curve it is seen that the chlorine of the effluents reached a nearly constant value (1·40 approximately) after about 18 hours from the time that water was turned on to the filter. This value was a little higher than that of the chlorine of the water, which may be taken at about 1·30.‡

If we take 18 hours as the time practically required for the chlorine of the septic liquor to be washed out of the filter by water, at the rate of 100 gallons per cube yard per day, and apply the method of calculation worked out in the Report on the Dorking Experiments,§ we get the *average time of contact* for this filter, in its

* *Cf.* the Accrington experiments, this Appendix.

† Septic liquor cut off and town's water substituted.

‡ No chlorine estimations were done on the water alone between 8.30 a.m. on June 19th and 1 p.m. on June 20th.

§ This Appendix, pp. 201 and 204.

then state and at the above rate of flow, as being about 3¼ hours. It does not follow—indeed, it is altogether improbable—that the passage of even soluble organic impurities through a percolating filter is as rapid as that of a soluble salt like sodium chloride. Still, the method gives good comparative results. It has already been discussed in detail in the Dorking Report by Mr. E. H. Richards (*loc. cit.*), and also by Mr. W. Clifford in his papers on the subject.*

The above method of determining the rate of flow through a percolating filter, by the difference between the chlorine content of the sewage liquor and that of the water supply, is simpler to carry out than the method followed at Dorking and Ilford (of adding to the sewage liquor a given volume of sodium chloride solution of known strength), provided water is available for turning on to the filter. To decide which is the more accurate, it would be necessary to make further determinations with water. So far as we are aware, this has not yet been done.

If Table B.W. be referred to, it will be seen that throughout the whole experiment almost all the nitrogen of the effluent was—practically speaking—in the form of nitrate, and this diminished in amount very slowly indeed. Thus, on June 19th, when the chlorine had become almost constant, the nitric nitrogen amounted to 0·60 part per 100,000, and it gradually fell to 0·13 part on September 30th, the lowest figure being 0·10 part on September 10th. This was hardly greater than the nitric nitrogen of the tap water, viz., 0·05 part. The oxidation of the accumulated nitrogenous organic matter in a percolating filter, which has been working properly, is thus a very slow process under the conditions described.

The gradation of the figures for nitric nitrogen in Table B.W. shows a distinct analogy to those in Tables 1 and 1 W. for contact beds (*cf.* this Appendix, p. 77). True, the oxidation of the nitrogenous matter was more complete in the case of the percolating filter, but a reference to Tables D and E† shows that there was very little sludge indeed and very little volatile matter in the material of this filter to start with, only about a tenth of the sludge of contact bed No. 1. Oddly enough, the percentage of nitrogen in these two sludges was practically the same (2·47 in No. 1 and 2·44 in B).

The earlier samples of the wash-out effluent from percolating filter B.W., though clear, had a brownish tinge, but they gradually became colourless. The suspended solids in the earlier samples appeared to be something like 2 parts per 100,000, as judged by the eye, and on the whole the quantity diminished as time went on (*cf.* centrifuge figures, below). But here again, as in the case of the oxidation of organic nitrogen, the process of clearing the filter of accumulated solids (which were present only in small quantity) went on very slowly.

Occasions might arise on a sewage works when it would be desirable to clear superfluous solids out of a percolating filter, by running water through it. By alternating rests with this water treatment, even a badly clogged filter of coarse material could probably be cleared pretty quickly, so far as it was desirable to go. The foregoing experiment shows that there need be no fear of the suspended solids being washed out of the filter at such a rate as to seriously affect its subsequent working efficiency.

We would again desire to acknowledge the great help which we have received from Mr. Boothman in the carrying out of these additional experiments at Accrington, including also the experiments which are described in the next paper of this Appendix.

TABLE B.W.

WASHING PERCOLATING FILTER B.W. WITH TOWN'S WATER, AT THE RATE OF 100 GALLONS OF WATER PER CUBE YARD PER DAY.

Parts per 100,000 by Weight.

No. of Sample.	Date of Drawing, 1908.	Ammoniacal Nitrogen.	Albuminoid Nitrogen.	Nitrous Nitrogen.	Nitric Nitrogen.	"Oxygen absorbed" in 4 hours from $\frac{N}{8}$ Permanganate.	Solids in Suspension.	Solids by Centrifuge (Vols.)	Chlorine.	Notes.
A 2	June 19	0·0009	0·0096	0·00	0·05	—	—	—	1·13	Town's Water.
A 6	June 21	—	—	0·00	0·05	—	—	—	1·28	Town's Water.
1143	Aug. 19	—	—	—	0·05	0·128	—	—	—	Town's Water.
A 1	June 19	0·20	0·13	0·03	1·47	2·44	Solids estimated by eye at about 1·5	The solids remained the same in appearance during this time	4·50	Effluent from treatment of septic liquor.
A 3	June 19	0·013	0·062	0·00	1·03	about 0·5			2·05	Water effluent.
A 4	June 19	0·003	0·057	0·00	0·60	—			1·47	Water effluent.
A 5	June 21	0·009	0·063	0·00	0·65	—			1·40	Water effluent.
A 7	June 22	0·010	0·080	0·00	0·75	—			1·26	Water effluent.
A 8	June 22–23	0·009	0·080	0·00	0·92	0·68			1·40	Water effluents, average samples made up of 3 or 4 sub-samples.
A 9	June 23–24	0·006	0·072	0·00	—	—	estimated at about 2	—	1·40	
1112	June 24–27	0·02	0·07	0·00	0·83	0·70	1·60	18·1	—	
1115	June 28–July 1	—	—	—	0·75	—	—	27·2	—	
1116	July 2–4	0·01‡	—	0·00	0·65	—	—	21·8	—	
1119	July 6–8	—	—	—	0·48	—	—	—	—	
1120	July 9–11	—	—	—	0·50	—	—	24·4	—	
1123	July 13–15	—	—	—	0·43	—	—	20·0	—	
1124	July 16–18	—	—	—	0·45	—	—	20·0	—	
1125	July 20–22	—	—	—	0·45	—	—	7·0	—	
1128	July 23–25	—	—	—	0·43	—	—	12·4	—	
1129	July 25–29	—	—	—	0·34	—	—	3·6	—	
1132	July 30–Aug. 1	—	—	—	0·30	—	—	10·4	—	
1133	Aug. 3–5	—	—	0·00	0·27	0·213	—	10·4	—	
1136	Aug. 6–8	—	—	0·00	0·26	0·220	—	11·2	—	
1137	Aug. 10–12	—	—	0·00	0·21	0·230	—	17·6	—	
1140	Aug. 19	—	—	—	0·23	0·274	—	20·8	—	
1144	Aug. 26	—	—	—	0·15	§ 0·260	—	17·2	—	Single samples of water effluent.
1147	Sept. 2	—	—	—	0·15	0·289	—	18·0	—	
1152	Sept. 9	—	—	—	0·17	—	—	10·4	—	
1153	Sept. 16	—	—	—	0·10	0·220	—	10·4	—	
X	Sept. 22	—	—	—	0·14	0·201	—	—	—	
Y	Sept. 30	—	—	—	0·13	0·191	—	—	—	

* The measurement of the velocity of water through Filter Media; Journ. Soc. Chem. Industry, No. 13, Vol. XXVII. (July, 1908). On Percolation Beds; *Proc. Inst. Civil Engineers*, Vol. 172, Part II.

† These Tables are appended to the memorandum on the action of certain . . . solutions on the accumulated sewage solids in contact beds (*Cf.* this Appendix, p. 75); the Tables are, however, only typed, but they are available for reference at the Office of the Commission.

‡ Estimated by direct Nesslerization. § Done as a water, with $\frac{N}{80}$ Permanganate, etc.

GEORGE McGOWAN.
COLIN C. FRYE.
A. F. GIRVAN.

PRELIMINARY EXPERIMENTS ON THE ACTION OF CERTAIN NITRIFYING, OXIDIZING, FERMENTABLE, AND DISINTEGRATING SOLUTIONS ON THE ACCUMULATED SEWAGE SOLIDS IN CONTACT BEDS, BY DR. G. McGOWAN, DR. A. C. HOUSTON, AND MR. COLIN C. FRYE.

These experiments were made chiefly with the object of seeing how far it was possible to stimulate the oxidation, or assist in the separation, disintegration and solution of the solids left in partially clogged contact beds. They were carried out at the Accrington Sewage works in the four experimental contact beds for septic tank liquor which have been already described, two primary and two secondary.*

These beds were constructed of brick and cement, and were filled with coke breeze; each of them was 10 feet long by 9 feet wide by 4 feet deep. The empty tank capacity of each of the primary beds was, approximately, 2,243 gallons, and that of each of the secondary beds, 2,224 gallons.

The grading of the coke was as follows:—

Primary Beds.—From 1 inch to 1½ inches in diameter, with a covering of fine coke (⅛ inch diameter) in the feeding grips.

Secondary Beds.—Between ¼ inch and ½ inch in diameter.

From May 5th, 1905, to January 18th, 1908 (excepting for a period of thirty weeks, from March 23rd to October 20th, 1907, when they were resting), the beds had received regular fillings of Accrington septic tank liquor, undiluted or diluted. (*Cf.* Accrington experiments, I. and II.)

The water capacities at the beginning and end of this period were as follows:—

TABLE A.

		Capacity in May, 1905. (gallons).	Capacity in January, 1908. (gallons).	Loss of Capacity.	
				Gallons.	Per cent.
Primary Beds	No. 1 - - - -	1,170	640	530	45
	No. 1 W. - - -	1,185	780	405	34
Secondary Beds	No. 2 - - - -	1,035	1,000	35	3
	No. 2 W. - - -	1,070	850	220	21

It may be remembered that Beds 1 and 2 treated the undiluted Accrington liquor, while 1 W. and 2 W. treated the liquor after dilution with water.

The two primary beds and one of the secondary beds (No. 2 W) had thus suffered a considerable reduction of capacity; the other secondary bed (No. 2) had undergone practically no reduction.

Since the measurements in January, 1908, were made soon after an unusually long rest had been given to the beds, the greater part of the reduction in capacity at that date might be regarded as of a more or less permanent character and irrecoverable in ordinary working. It will thus be seen that the experiments about to be described were carried out under very unfavourable conditions.

On January 21st and 22nd, 1908, the beds were filled with the following mixtures:—

Primary Bed No. 1 (*Capacity,* 640 *gallons*).

	Approximate weight.	Approximate percentage, by weight.
Sulphate of ammonia - - -	7·5 lbs.	0·12
Sulphate of magnesia - - -	7·5 „	0·12
Phosphate of soda - - -	7·5 „	0·12
Carbonate of lime (whitening) -	7·5 „	0·12
Water - - - - - -	640 gallons.	

This mixture was intended as a nutrient solution for nitrifying organisms.

The sulphates of ammonia and magnesia were first dissolved in some water, the whitening being stirred in afterwards; the phosphate of soda was dissolved in a separate portion of water. Both solutions were then gradually added to the main bulk of the water as the bed was being filled.

Primary Bed No. 1 W. (*Capacity,* 780 *gallons*).

	Approximate weight.	Approximate percentage, by weight.
Nitrate of soda - - - -	80 lbs.	1·07
Phosphate of soda - - -	16 „	0·20
Water - - - - - -	750 gallons.	

This was intended as an oxidizing solution. The two salts were dissolved in a cistern of water, the solution being gradually added to the main body of the water as the bed was being filled.

* The Accrington experiments; this Appendix, p. 52.

Secondary Bed No. 2 (Capacity, 1,000 gallons).

	Approximate weight.	Approximate percentage, by weight.
Cane sugar - - - - -	96 lbs.	0·95
Water - - - - - -	1,010 gallons.	

The object of adding this solution was to set up an active carbonaceous fermentation.

The sugar was dissolved in a cistern of water, and the solution was added to the bulk of the water, as before.

Secondary Bed No. 2 W. (Capacity, 860 gallons).

	Approximate weight.	Approximate percentage, by weight.
Crude caustic soda - - -	84 lbs.	1·0
Water - - - - - -	830 gallons.	

This liquid was intended as a disintegrator and solvent of organic matter.

The solution of soda was made and added in the same way as that of the sugar.

It was intended to allow the above four solutions to remain in the beds for a period of fully three months, but, unfortunately, the secondary beds were found to leak somewhat rapidly; the contact in their case did not last beyond twenty-three days, and that over a gradually diminishing internal surface area. By February 7th, indeed, *i.e.*, in sixteen days from the start, both the secondary beds, Nos. 2 and 2 W., were nearly empty, and samples of the residual solutions had, therefore, to be drawn from them on that day. These beds were drained off completely on February 14th.

Primary bed No. 1 W. was found to be about half full of liquid on March 7th, and one-third full on March 18th, when a sample of the nutrient solution was taken; it remained about one-third full until April 27th, when it was drained off.

Primary bed No. 1 remained full for the whole period, *i.e.*, from January 22nd to April 27th. A sample of its solution was, however, drawn on March 18th.

The following table shows the *immediate* effect of the treatment on the capacities of the beds:—

TABLE B.

	Nature of solution.	Number of days solution was in contact.*	Water capacity, when solution was added (gallons).	Water capacity, after solution was run off (gallons).
Primary Bed No. 1 - - -	Nitrifying -	96	640	630
Primary Bed No. 1 W. - -	Oxidizing -	96	780	800
Secondary Bed No. 2 - - -	Carbonaceous (Acid) -	23	1,000	1,040
Secondary Bed No. 2 W. - -	Caustic - -	23	850	860

There was thus, *at this stage*, no great difference in the capacities of the beds, as compared with what they were at the beginning of the experiment, excepting that the gain of 40 gallons in the case of secondary bed No. 2 meant the recovery of its original capacity (when newly filled with coke).

Treatment of the Beds with Water.

After the beds had been emptied of their various solutions, they each received two fillings per week of Accrington town's water until October 5th, 1908, *i.e.*, for a period of fully five months, the duration of the contact being 2 hours in every case. The capacities on October 5th (at the end of the water treatment), as compared with those on April 27th (before the water treatment commenced), were as follows:—

TABLE C.

Capacity in gallons.	April 27th, 1908.	October 5th, 1908.	Gain.
Primary Bed No. 1 - -	630	710	80
Primary Bed No. 1 W. - -	800	900	100
Secondary Bed No. 2 - -	1,040	1,150	110
Secondary Bed No. 2 W. -	860	1,070	210

* Subject to what is said about leakage.

In order to contrast without trouble the effect of the four different methods of treatment, it will be convenient to bring the main results of the gauging into one table :—

TABLE D.

Capacity in gallons.	May 5th, 1905, when bed was new.	January 18th, 1908, when the solution was run into the bed.	(*a*) April 27th and (*b*) February 14th, 1908, when the liquor was run out of the bed.	October 15th, 1908, after the treatment with water.	Ultimate gain or loss of capacity, as compared with the new bed.	
					Gallons.	Per cent.
No. 1 Primary - -	1,170	640	(*a*) 630	710	− 460	− 39
No. 1 W. Primary -	1,185	780	(*a*) 800	900	− 285	− 25
No. 2 Secondary -	1,035	1,000	(*b*) 1,040	1,150	+ 115	+ 11
No. 2 W. Secondary	1,070	850	(*b*) 860	1,070	0	0

As the result of the whole treatment, the primary beds Nos. 1 and 1 W. regained only 70 and 120 gallons capacity of the 530 and 305 gallons which they had lost up to January, 1908.

In *Primary Bed No.* 1, the ultimate diminution of capacity from 1,170 to 710 gallons was apparently due to a large extent to the presence of some very resistant organic matter. Nitrification was probably going on all the time the nutrient solution was in contact with the filtering material, but the nitrate (or nitrite) formed was immediately used up in oxidizing the carbonaceous matter present.

In *Primary Bed No.* 1 *W.* the added nitrate had been very largely drawn upon, prior to March 18th, for the oxidation of the organic matter in the bed. As the result of the whole treatment (with solution of nitrate of soda and with water), the bed had recovered only about one-third of the capacity which it had lost during its two and a half years' work with septic tank liquor.

Both the secondary beds, however, were brought back practically to their original water capacities of 1905. Indeed, *Secondary Bed No.* 2, though it had not much capacity to recover in January, 1908, showed as the result of the combined sugar and water treatment a gain of 115 gallons on the original capacity of 1905.* The fermentation induced in the sugar solution was an acid one. It looks, therefore, as if the acid produced by the fermentation of the sugar had had a loosening or solvent action upon the clogging matter of the bed.

In the case of *Secondary Bed No.* 2 *W.*, the recovery of capacity due to the combined soda and water treatment was 220 gallons.* The solvent action of the soda upon the organic matter accumulated in the bed was very marked. Further, nitrification was not long in re-asserting itself after the soda solution had been run off and the washing with water had begun.

The most striking feature of the bacteriological results is to be found in the almost complete absence of B. coli from the various solutions left in contact, for a long period, with the material in beds which had become partially choked as the result of prolonged treatment of sewage (*i.e.* of septic liquor). Inferentially, the results suggest that the "sewage matter" accumulating in such beds would not favour the development (or even the persistence) of pathogenic bacteria, such as the typhoid bacillus.

Provisional Conclusions.

It is only possible to make a fairly good comparison between the first two and the second two pairs of beds, respectively :

(1) Because the size of the material was greater in the primary beds.

(2) Because the primary beds treated septic liquor, while the secondary beds treated primary effluent ; and

(3) Because the secondary beds leaked much more than the others.

Primary Beds.—There was a greater gain of capacity in No. 1 W. than in No. 1, and the mechanical and chemical analyses of samples of the bed material indicated on the whole that the residual material of No. 1 (*i.e.*, coke plus extraneous matter) was rather the more spongy of the two. It will, further, be remembered that No. 1 W. leaked appreciably. Hence, the conclusion seems justified that the effect of adding nitrate solution to No. 1 W. was, on the whole, rather greater than the effect of the nitrifying solution added to No. 1, though there was not very much difference.

Secondary Beds.—Both of these leaked rather rapidly, so that neither received the full benefit of the solution added to it. The effect of the caustic solution on No. 2 W. was greater than that of the sugar solution on No. 2, but there was more clogging material to be acted on in the former case. While both solutions, therefore, did well, it is difficult to say which did the better. Further, both of these were probably more efficacious than either of the solutions applied to Nos. 1 and 1 W.

The clearing action of a solution of caustic soda upon partially clogged percolating filters has been well shown in connection with the experiments of the Commission at Coleburn † and at Dorking, and the above results go to indicate that it might also be applied practically to contact beds in certain cases.

It would be interesting to see some experiments of this kind repeated on a larger scale. The sewage liquor ordinarily treated on the bed might be used, instead of water, to wash out the residual nutrient or other solution. Provision would, of course, have to be made for returning the foul liquor of the first few emptyings, either on to land or into a settling or septic tank, where it would be greatly diluted. A solution of caustic soda would probably be found to act more quickly in the way of relieving a clogged bed than one of sugar, but, on the other hand, its use might possibly affect for a little time the subsequent nitrification in the bed. The same soda solution might be used more than once, if circumstances allowed of this.

Since the results of the foregoing experiments are to some extent indeterminate, only the main points arrived at have been specified in this paper. A more detailed statement, with chemical and bacteriological tables of analysis of the various liquors and wash-out effluents, and with tables giving the mechanical and chemical analyses of the filter-bed materials, is at the office of the Commission in typed form, and may be referred to by anyone interested in the subject.

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November, 1909.

* *Cf.* paragraph upon the loss of capacity in the Accrington experiments; this Appendix, pp. 57 and 61.

† Sixth Report, Appendix II., p. 24.

REPORT ON EXPERIMENTS WITH SEWAGE SLUDGE ON GRASS LAND, CONDUCTED AT THE WOBURN EXPERIMENTAL FARM, BEDFORDSHIRE, IN 1908, BY DR. J. A. VOELCKER.

A desire having been expressed, by the Royal Commission on Sewage Disposal, that the experiments of 1907* should be carried on for another season, this was accordingly arranged. No further applications were put on the grass plots, but the grass—after being grazed over with cattle in the autumn—was put up for hay and the produce of the different plots weighed.

It is only necessary to repeat here that the field on which the experiments were conducted was on the junction of the Lower Greensand with the Oxford Clay, and that it had long been in grass, which, however, was of but moderate quality. Seven different kinds of Sludge were tried, the analyses of which are given in full in the 1907 report. No. 1 was the poorest in lime and richest in nitrogen, Nos. 6, 5 and 3 following in respect of richness in nitrogen and smaller lime content, while Nos. 7, 2, 4 came next, No. 4 being the lowest of all in respect of nitrogen and Nos. 2 and 4 the richest in lime.

The applications of Sludge had been (in February, 1907), in such quantities that in each case 40 lbs. of nitrogen were supplied per acre. The results for 1907 were given in the former report and showed generally that the Sludges "told" very little. The season was, however, a quite exceptional one, marked by there being very little rain in February and March, and an absence of warmth later on. Under such circumstances it was felt that the applications had but little chance of making their influence felt, and it was decided to see what they would do in a second year.

After removal of the hay crop of 1907 the land was grazed over with bullocks in the autumn, and early in 1908 it was chain-harrowed and rolled. The month of February was again very dry, only ·85 inch of rain falling; the temperature was also high for the month. March and April were colder, and the rainfall more, viz., 2·86 inches in March and 3·74 inches in April. It was not until May that the grass really began to grow, the cold spring militating much against its progress. Even as late as June the treated plots looked but little better than the rest of the field. Notes were taken of the appearance of the herbage, but there was little definite to be found in this respect between one plot and another. At the beginning of July the grass was ready for cutting, and it was made into hay on July 3rd, the weights being duly recorded as below. For the convenience of comparison, the results of 1907 and 1908 are put side by side.

Weights of Hay per acre, July 15th, 1907, and July 3rd, 1908.

Plot.	Application per acre in 1907.	1907.	1908.	Total of the two years.
		cwts.	cwts.	cwts.
1	Sludge No. 1 (= Nitrogen 40 lbs.)	39·9	25·4	65·3
2	" " 2 " "	43·5	30·7	74·2
3	" " 3 " "	43·4	22·7	66·1
4	" " 4 " "	44·4	26·2	70·6
5	" " 5 " "	43 5	20·5	64·0
6	" " 6 " "	42·8	28·2	71·0
7	" " 7 " "	47·2	29·4	76·6
8	Superphosphate 3 cwt.; Lime 5 cwt.	45·4	33·6	79·0
9	No treatment.	46·8	33·5	80.3
10	Superphosphate 3 cwt.; Lime 5 cwt.; Sulphate of Ammonia ¾ cwt.	48·2	36·4	84·6
11	Superphosphate 3 cwt.; Lime 5 cwt.; Sulphate of Ammonia 1½ cwt.	63·2	32·5	95·7

It will be seen that the hay crop of 1908 was poor, and much smaller than that of 1907. The only plot which showed any increase over the unmanured plot was plot 10, on which sulphate of ammonia had been used in 1907 in conjunction with superphosphate and lime. The produce of the sludge plots was in every case lower than on the untreated plot. The conclusion must, however, be come to, that plot 9 (untreated) was probably better land than that of the sludge plots, for it is hardly reasonable to suppose that the sludges could have done any actual harm by their application. Moreover, the fact that the application of artificial manures on plot 8 and on plot 10 did not largely increase the crop, would indicate also that plot 9 was better land than the rest, and that it was hardly fair to take it as as a basis of comparison. As regards the applications of sulphate of ammonia in 1907, it will be seen that there was but little effect from these in the second year. Comparing the different sludges one with another, the most marked differences were with sludges Nos. 2 and 7, both of which, it should be noted, contained high proportions of lime. Sludge No. 1, which was the richest in nitrogen but poorest in lime, gave a comparatively low return.

Taking the two years together, the general conclusion will be come to that the artificial manures produced larger crops of hay than did any of the sludges. As pointed out in the 1907 report, the artificial dressings on plots 10 and 11 supplied only 16·8 lbs. (plot 10) and 33·6 lbs. (plot 11) of nitrogen per acre, as against the 40 lbs. per acre given in the sludges, while neither phosphoric acid nor lime were in excess of what was supplied in the sludges, with the single exception of sludge No. 1, which was very low in lime. Therefore the larger crops were not due to any excessive supply of manurial ingredients in the artificials. It is evident, therefore, that the nitrogen in the sludges is not in as available a form for hay production as it is in artificial manures, and that its benefit is not apparent even when a second season is allowed to pass. The use of sulphate of ammonia in the artificial applications was, it is true, far more marked in the first year, and its influence in the second year was but slight; but, though this was the case, the presumably more slowly-acting nitrogen of the sludges did not succeed in "telling," even when the trials were extended to a second season.

These results would, therefore, throw much doubt on the generally accepted belief that sewage sludge, though it may not immediately show the results of its application, will "tell" in the long run. Further, the fact that the sludge that was richest in nitrogen gave, over the two years, the lowest result but one, would confirm the conclusion that the richness of a sewage sludge in nitrogen is not the best indication of its comparative value. What is noticeable, however, is that the sludge plots which produced the highest crops over the two years were Nos. 7 and 2, and that both of these contained high amounts of lime. Sludge No. 4, which was the second richest in lime, though poor in nitrogen, gave the fourth best return. The conclusion would, therefore, seem to be justified that in these sludges the presence of lime is decidedly beneficial, and that lime has probably to do with making what nitrogen is contained in the sludge available, otherwise there would not have been the comparative failure with the sludges richer in nitrogen but poor in lime.

Were these conclusions based on the weights of hay alone they would, as pointed out in the 1907 report, be

* See Appendix VIII. to Fifth Report of Royal Commisson on Sewage Disposal.

open to the objection that this was not the real test of improvement of the pasture. But, in addition, botanical examination and actual separation of the constituents of the pasture have been made in the case of all the plots. These do not show any material difference between the various plots, or any increase in the leguminous constituents, and it is unnecessary, therefore, to give the results in detail.

Continuation, therefore, of the experiments has not shown that the manurial effect of the sewage sludges was equal to that of corresponding dressings of artificial manures, even when a second season was taken into account. As regards different kinds of sewage sludge, the further conclusions are come to that the nitrogen is not present in a valuable or available form, and that the amount of nitrogen present is not in itself a test of the comparative value of different sludges. On the other hand, lime would appear to be a desirable constituent of sewage sludges, and it is probable that it exerts a beneficial influence in rendering the nitrogenous organic matter available as plant food.

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July, 1909.

EXPERIMENTS WITH SEWAGE SLUDGES CONDUCTED AT THE POT CULTURE STATION OF THE WOBURN EXPERIMENTAL FARM IN 1908, BY Dr. J. A. VOELCKER.

In 1907, by desire of the Royal Commission on Sewage Disposal, the Royal Agricultural Society of England, carried out, at the Woburn Farm, an extended series of trials with seven different kinds of Sewage Sludge supplied to them by the Royal Commission.* These experiments were on the wheat crop, and, the desire being expressed that the work should be continued for a second year without any further applications being given, this was accordingly done, barley being the crop grown in 1908.

There was made, in 1907, not only a comparison of one kind of sludge with another, but these were generally compared with "artificial equivalents" in the shape of fertilisers, so that an idea could be formed of the respective money values of the different sludges. The entire series was carried out by Pot culture methods, these lending themselves particularly well to the simultaneous conduct of a large number of trials, and in a way that would be difficult in the case of field experiments. Moreover, the observations which it was possible to make throughout were thereby of additional value, and the duplication of experiment removed to a large extent any disturbing factors in the results.

The analyses of the seven different sludges are given in the 1907 Report, and it is enough to mention here that the main differences between them were in respect of the moisture, the nitrogenous organic matter, and the lime which they severally contained. Sludge No. 1 was the second driest (moisture 8·04 per cent.), the richest in nitrogen (2·24 per cent.) and the poorest in lime (3·87 per cent.). Sludge No. 6 was the driest of all (moisture 3·55 per cent.), the third highest in nitrogen (1·42 per cent.), and the second lowest in lime (9·48 per cent.). On the other hand, Sludge No. 4 was the highest in moisture (38·5 per cent.), the lowest in nitrogen (·53 per cent.), and the second highest in lime (25·17 per cent.). The highest in lime was Sludge No. 2, containing 26·67 per cent., while it had 27·38 per cent. of moisture and only ·917 per cent. of nitrogen. The other sludges held intermediate positions, not differing widely from one another in respect of moisture (11·38 to 14·04 per cent.), or of nitrogen (1·03 to 1·56 per cent.), while the lime ranged from (12·42 per cent. to 18·17 per cent.). Accordingly, Sludges 1 and 6 may be taken as representative of sludges dry in character, rich in nitrogen, but poor in lime; while Sludges No. 2 and 4 were characteristic of sludges of moist nature, low in nitrogen, but rich in lime.

Each sludge was applied, according to the plan suggested by the Royal Commission, at a rate to supply 40 lbs. of nitrogen per acre, and, to correspond with these applications, artificial mixtures, composed of superphosphate, rape dust, and lime, were given, supplying the like amounts of manurial constituents.

Thirdly, with the idea of getting at the actual money value of the sludges in practice, a further set of experiments was set out in which three of the sludges (Nos. 1, 2, 3), applied at a farmer's rate of 2 tons per acre, were compared with artificial dressings (superphosphate, sulphate of ammonia, and lime) costing respectively 23/- and 30/- per acre.

Each experiment was in triplicate, so as to provide checks on the results obtained, and 69 pots in all were used. Details of the filling of the pots. applications of manures, analyses of the soil, manures, &c., are given in the 1907 Report.

The general conclusions formed as the result of the wheat experiments of 1907, were :—

1. That the different sludges, applied to supply 40 lbs. of nitrogen per acre, increased the yield of corn and straw by 10 to 12 per cent. over no treatment.

2. That the increase was not so great—by about 5 per cent.—as that from artificial equivalents of the sludges.

3. That the use of sludge tended to give increased length of straw.

4. That the sludges that did best were those which contained most moisture and most lime, and not those richest in nitrogen.

5. That 10/- a ton would represent the full value, on the farm, of the best of the sludges.

It was desired now to see whether another year's experience, by taking a second corn crop (barley) without further application of manure, would modify in any way, or confirm, the above observations. It was considered possible that the sludges, being more or less slow in their action, would not have exhausted their benefit with the wheat crop, but that something might be left over for a second crop, while this might or might not be the case with the "artificial equivalents" with which they were compared.

After the wheat crop of 1907 was harvested, the soil in the pots was broken up for 3 inches depth, the wheat stubble being turned in, just as would be the case in the field. There was nothing to note as regards any differences of appearance in the roots of the different sets. In February, 1908, a mossy growth was noted on the surface of some of the pots, the particular ones being those which had the most lime; this continued throughout and was again noticed very markedly after the barley was harvested. Special reference will be made to this later. In March, 1908, the root growth was again broken up, and this process was repeated later on, so as to get even distribution throughout the soil. On April 4th, 1908, "Malster" barley was sown, twelve seeds in each pot. The seeds came up well, almost without exception, and there is nothing particular to record as regards any differences shown in germination. In no case did the germination fall below 80 per cent. On May 21st, by which time no differences in the plants were observable, the number of plants was reduced to six per pot, the usual quantity kept to. Cold nights during April retarded growth, but, early in May, there was improvement; rain, too, fell, and the plants made good progress. In June, however, there was high temperature and very little rainfall (1·47 inches only for the month), so that the plants fell away somewhat and did not "tiller out" well. In July the untreated plots looked about as good as any of the others, while, as between the sludges, No 2 was perhaps the best. The crops were very free from "smut" and fungoid attacks throughout. By August 17th the barley was ready to cut, the different lots were photographed, and the produce was harvested on August 23rd. The following table gives, in the same form as that adopted with the wheat experiments of 1907, the barley results for 1908 :—

* *See* Appendix VIII. to Fifth Report of Royal Commission on Sewage Disposal.

Sewage Sludge Experiments, Woburn 1908, on Barley, after Wheat (Pot-culture).

Harvest Results, giving average length of Ear and Straw, average number of Ears and Grains, average weight of Corn and Straw, &c.

Series.	No. of Pots.	Treatment in 1907.	Average length of		Average number of		Average weight of		Produce as percentage of untreated.	
			ear.	straw.	ears.	grains.	corn.	straw.	corn.	straw.
			inches.	inches.			grms.	grms.	o/c	o/c
A*	6	No treatment (control) - - -	2·07	14·82	8·8	132	6·04	6·60	100·0	100·0
	2	Sludge No. 1 - - - - - -	2·04	13·66	8·5	122	5·27	5·85	87·2	88·7
	3	" " artificial equivalent -	1·89	14·12	8·3	114	5·13	5·44	84·9	82·6
	3	Sludge No. 2 - - - - - -	2·23	15·29	10·0	177	7·74	8·05	128·1	122·3
	3	" " artificial equivalent -	2·18	14·89	9·7	154	7·09	7·08	117·4	107·3
	2	Sludge No. 3 - - - - - -	2·05	14·50	9·5	145	6·59	6·53	109·1	98·9
	3	" " artificial equivalent -	2·03	14·95	8·7	131	5·74	5·98	95·3	90·6
	3	Sludge No. 4 - - - - - -	2·21	15·76	13·0	204	9·20	10·43	152·3	158·0
	3	" " artificial equivalent -	2·20	16·20	10·0	159	7·22	7·12	119·3	107·8
	3	Sludge No. 5 - - - - - -	2·21	15·65	6·0	94	4·61	5·52	76·3	83·6
	3	" " artificial equivalent -	2·21	14·90	7·3	120	5·56	5·64	92·0	85·5
B†	2	No treatment (control) - - - -	2·01	14·21	6·0	88	4 03	4·61	100·0	100·0
	3	Sludge No. 6 - - - -	1·79	13·18	7·0	93	3·47	4·68	86·1	101·5
	3	" " artificial equivalent -	2·08	14·54	5·7	95	4·34	4·39	107·7	95·2
	2	Sludge No. 7 - - - - -	2·22	13·57	4·5	83	3·20	4·95	79·4	107·4
	2	" " artificial equivalent -	2·23	15·73	5·0	77	3 86	4·36	95·7	94·6
C†	3	No treatment (control) - - - -	1·83	13·41	8·5	122	4·88	6·37	100·0	100·0
	3	Sludge No. 1, 2 tons per acre - -	2·03	14·10	8·0	119	4·68	6·43	95·9	100·9
	2	" No. 2, 2 " - -	1·97	13·57	8·0	121	4·99	5·14	102·2	80·7
	2	" No. 3, 2 " - -	2·07	14·16	8·0	120	4·97	5·92	101·8	92·9
	2	Superphosphate 2 cwt.; Lime 5 cwt.; Sulphate of Ammonia ¾ cwt.; per acre, cost 23*s.* - - - -	2·01	14·70	6·5	95	4·42	4·85	90·6	76·1
	3	Superphosphate 3 cwt.; Lime 10 cwt.; Sulphate of Ammonia 1 cwt.; per acre, cost 30*s.* - - - -	1·95	13·99	8·0	108	4·74	5·33	97·1	83·6

* 40 lb. soil per pot. † 32 lb. soil per pot.

It will be noted that in compiling the foregoing average results those pots have been left out of account which, owing to accidental circumstances, did not give results in accordance with the other duplicate ones.

Examining now the results in detail and comparing them with those obtained in 1907 with the wheat crop, one observes, in the first place, that the barley crop was decidedly poor, giving only about one quarter the weight of the wheat. Next, the increases, where any occur, over the untreated produce, are but small, and bring out that there is but little left, after a wheat crop, for a second corn crop, from a dressing of sludge or its equivalent in artificial manures. The same point is brought out where 2 tons of sludge to the acre were used, while the artificial manures costing 23*s.* and 30*s.*, respectively, had also exhausted their effects with the wheat crop. There is little, therefore, to lead one to look in a second season for any decided influence on direct crop-bearing from the use of sludge. In other words, the "lasting" effect of it has not been established. Whether or not, attending its use, there be mechanical and physical advantages accruing to the land on which sludge is used is a different point, but one which pot-culture experiments are not calculated to bring out.

As between the sludges and their artificial equivalents, there is little to choose, and the superiority of the latter noticed with the wheat crop in 1907 disappears, the sludge indeed, in 4 cases out of 7, giving the higher corn yield.

As regards number of ears, length of straw, &c., Sludge No. 4, and, to a lesser extent, Sludge No. 2, were the only ones to increase the number of ears and number of grains materially, while Sludge No. 4 alone increased the length of straw. These two sludges, it will be remembered, were the ones richest in lime, but poor in nitrogen, and possessing much moisture. There was not the tendency, noted in 1907, for the sludges to produce a longer straw.

Comparing next the different sludges one with another, it may be said that Sludge No. 1, the richest in nitrogen but poorest in lime, gave, all round, the worst results. This had been also the case with the wheat in 1907, Sludge No. 5 was little or no better, while Sludges Nos. 3, 6 and 7 were all of them just about the same, on the average, as the untreated plots. The only dressings which have given any consistent gain are those of Sludges Nos. 2 and 4, the ones richest in lime. This is the same result as was brought out in 1907 with the wheat crop, and would confirm the conclusions then arrived at that the value of sewage sludges is not marked so much by the nitrogenous organic matter they contain as by the lime, and, further, that it is desirable to have a sludge in a moist condition rather than very thoroughly dried. As regards, lastly, the application of some of the sludges at the rate of 2 tons per acre, this did not leave anything material for a second crop, nor, it is fair to say, did the artificial applications costing 23*s.* and 30*s.* per acre respectively. The outside value of 10*s.* per ton put last year on the best of the sludges is, therefore, a maximum one, even when subsequent crops are to be taken into consideration.

CONCLUSIONS (BASED ON THE RESULTS OF THE EXPERIMENTS OF 1907 AND 1908.)

1. That the different sewage sludges, when used in quantity to supply 40 lbs. of nitrogen per acre, will benefit a wheat crop to which they are applied, increasing both corn and straw to the extent of 10 to 12 per cent. above the unmanured produce.

2. That the increase of produce in the first crop (based on the results of the experiments of 1907 and 1908) will not be as much, by 5 or 6 per cent., as that obtained with "artificial equivalents" supplying the same constituents in equal amount.

3. That, after taking a wheat crop, sewage sludge or its equivalents in artificial manures leave practically nothing over for a second corn crop.

4. That, of different sewage sludges tried, those which show the most benefit for a wheat crop to which they are applied, and which leave most remaining over for a second corn crop, are those which are moist in character and which contain much lime.

5. That nitrogenous organic matter is not the determining factor in the value of sewage sludge, but that it is in an inert condition which requires the use of lime to bring it into action.

6. That 10/- a ton, on the farm, is an outside figure for the value of such sewage sludges as have been examined, even when a crop subsequent to that to which the sludge has been directly applied is also taken into account.

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Royal Agricultural Society of England.

July 1909.

NOTE ON GREEN GROWTHS FOUND ON CERTAIN OF THE SOILS.

It had been observed that on certain of the pots a green growth—as if of mosses or algæ—was spreading, and that this continued to increase, remaining after the crop (barley) had been removed.

The pots on which it occurred were noted, and its presence was found in special abundance on the following :—

(*a*) the three to which Sludge No. 2 had been applied.

(*b*) the three "equivalents" of Sludge No. 2.

(*c*) the three to which Sludge No. 4 had been applied.

(*d*) the three "equivalents" of Sludge No. 4.

The above, it will be noted, were the sets to which the most lime had been applied. Other sets, *e.g.*, No. 7, showed the same appearance, but to a lesser extent.

Specimens of the growth were collected and sent to Kew, where, by the kindness of Mr. A. D. Cotton, they were examined, Mr. Cotton reporting that the growth was much the same in each case, and consisted mainly of mosses of different kinds (*Bryum sp.*, *Pottia trubeatula*, &c.), Liverworts (*Riccia glauca*) and Algæ (*Vaucheria terrestris*). While this growth was not remarkable in itself, it is worthy of note that it was found principally on the soils where lime was present in largest quantity, and this whether lime had been applied direct (as with the "equivalents") or in the sludges themselves. Where the mosses &c., grew best, there the corn crop had flourished most. This would seem to indicate that the presence of lime in the sludges—up to, say, 25 per cent.—is very desirable, and that without a sufficiency of lime the nitrogenous matter of the sludges does not get broken down and made available.

[J.A.V.]

EXPERIMENTS WITH SEWAGE SLUDGE UPON HAY.

EFFECT OF THE RESIDUES OF MANURES APPLIED IN THE WINTER OF 1906-7 ON THE HAY CROPS OF 1908.

BY MR. T. H. MIDDLETON.

In 1907 experiments were carried out on eight farms in widely separated districts of Great Britain, for the purpose of testing the effects produced by application of various sewage sludges on the hay crop. An account of these experiments was published in Appendix VIII. to the Fifth Report of the Royal Commission on Sewage Disposal. It was shown as a result of the experiments of 1907 that, in the case of the four northern stations (Aberdeen, Glasgow, Newcastle, and Leeds), the sludges had increased the crop by from 5 to 9 cwt. per acre over the yield of 32 cwt. harvested on unmanured land, while in the case of the four southern stations (Bangor, Cambridge, Rothamsted, and Wye), no increase was obtained. From the appearance of the growing crops and other considerations, the increase produced by the sludges was attributed to the nitrogenous compounds which they contained. As these nitrogenous compounds exist in a slowly available form, and as, moreover, some of the sludges contained considerable quantities of phosphates and of lime, it was anticipated that after the harvest of 1907 considerable manurial residues would remain for subsequent crops. With the view of testing the effect of these residues, arrangements were made for the continuance of the experiments at five stations. In no case was any fresh application of manure made to the plots under experiment, and there was no special treatment until after the grass was cut, when the produce of each plot was dried and weighed as hay.

The spring of 1908 was unusually late, the temperature in the second half of April was low, and towards the end of the month there were several heavy falls of snow. A cold April was succeeded by a dry May and a dry, very hot June. The weather conditions were therefore unfavourable for a good hay crop and very unfavourable for bringing out the effects of slow-acting manures. For this purpose moist and warm "growing" weather is wanted between the middle of April and the middle of May. In a cold April the only manures likely to assist a hay crop are such readily available fertilisers as nitrate of soda or sulphate of ammonia, while if May is dry, the development of the herbage is limited by the available supplies of moisture, and manures have little chance of increasing the crop.

The results obtained in the experiment of 1908 are set out in the accompanying table A. For the sake of convenience the manures applied in the winter of 1906–7 have been shown, together with the values of the artificial manures, but the figures denoting yield relate only to crops produced in 1908. It has been considered undesirable to complicate the table by introducing the results of 1907, as these have already been published.

If the crops of 1908 are examined, it will be seen that a considerable increase has resulted on one or two of the sludge plots, as, *e.g.*, on Plot 7 at Glasgow, and Plots 1 and 2 at Rothamsted ; but if the yields are compared with the produce obtained from other plots at the same station, it will be apparent that the favourable results on these plots are accidental. Thus, at Glasgow, Plot 11 received one and a half times the dressing of sludge given to Plot 7, but instead of a further gain there was a loss of crop. It is highly improbable that an additional dressing of sludge could have injured the herbage, but even if the results obtained on Plot 11 are discarded as being possibly due to an excessive application of sludge, the crops obtained from Plots 12, 13, and 14 would serve to throw suspicion on the results of Plot 7. Again, in the case of Rothamsted, it is much easier to explain the increase on Plots 1 and 2 by assuming that the soil was better at one side of the field than elsewhere, than on the assumption that Sludges 6 and 7 were superior to those used on the other plots, for no evidence of superiority is to be found in the results obtained at the other stations.

Setting aside, therefore, increases which are almost certainly due to other influences than the special manuring, the conclusion to be drawn from the figures as a whole is that there is no definite evidence of any effective manure residue in the case of any one of the sludges applied to the land in the winter of 1906–7.

But though no evidence of a positive character is available, the figures in the Table supply evidence of another kind which must now be noted.

In addition to the sludges, certain of the plots received standard artificial manures, and in their case the residual value was also tested. It will be seen that just as in the case of the sludges no definite results were obtained from the residues of these artificial manures. In one respect this is satisfactory, for it shows, as has already been argued, that the conditions under which the test was made were unfavourable.

The effect of the residue of an application of sulphate of ammonia is not usually visible on a hay crop, and no definite conclusion can therefore be drawn from a comparison of the effects produced by nitrogen in the artificial manures and the sludges. The nitrogen in the sludges has in this particular season produced no increase, but the same result might have followed had a slow-acting artificial manure, such as bone-meal, been employed. But in the case of the phosphatic manure and the lime a comparison is possible, as both remain in the soil available for vegetation for a considerable time. In the case of the latter, it will be seen that no result has followed the application of quick-lime, even at Glasgow, Leeds and Cambridge, where the quantities used were in excess of the lime supplied in any of the sludges. With respect to the former, it may be observed that although not more than 100 lbs. per acre of basic slag was applied, and though no marked effect could be expected from the residue of so small a quantity, yet the weight of phosphoric acid applied in the standard manure was greater than the weight

supplied by Sludges 2 and 3, equal to the amount in Sludge 7, and nearly as much as was contained in Sludges 3 and 6.

If therefore any conclusion is drawn about the phosphates present in these sludges, it must be that under the conditions of the test these residues are no more effective than the residues of basic slag. Similarly, it may be concluded that there is no evidence showing the lime in the sludges to be any less effective than ordinary lime.

The only plots receiving an amount of phosphates approaching that which would be contained in an ordinary manuring were those dressed with Sludge No. 1. Plot 11, especially, which received about 60 lbs. phosphoric acid per acre, might have been expected to show some distinct advantage, but there is no evidence of this in the records of four out of the five stations.

In the fifth case, Cambridge, there is some slight indication of an effect, and it will be desirable to examine the results from there further.

In the Cambridge experiment every plot was duplicated and there were three unmanured plots. The soil was a medium loam overlying gault, but largely derived from gravel. In favourable seasons such soils respond freely to applications of either basic slag or superphosphate, but in a year like 1908 very little effect would be expected. The field was quite flat and apparently uniform, but in the absence of rain very slight differences in the physical texture and depth of the soil would, by affecting the moisture supply, greatly influence the yield. This disturbing effect of season is clearly shown by the Cambridge plots.

In addition to the manures used in the general experiment, the Cambridge experiment tested some other common fertilisers.

It will be unnecessary to give the whole of the Cambridge results, as most of them have already been given in the general Table, but a few figures of interest are brought together in the following statement.

Plot.	Manures per acre.	Per acre. Plot. A.	B.	C.	Average.	+ or –, as compared with no manure plots.
		cwt.	cwt.	cwt.	cwt.	cwt.
10	No manure	12·75	12·75	20·0	15·2	—
30	Complete artificial manure. { 20 lbs. Nitrogen. 40 lbs. Phosphoric Acid. 20 lbs. Potash. }	12·0	15·75	—	15·9	+ ·7
32	Ditto. but Phosphoric acid omitted	12·75	14·0	—	13·4	– 1·8
28	10 cwt. Basic slag (200 lbs. Phosphoric acid)	20·5	15·75	—	18·1	+ 2·9
7	1,724 lbs. Sludge No. 1 { 40 lbs. Nitrogen. 39 lbs. Phosphoric Acid. }	16·25	14·0	—	15·1	– ·1
11	2,586 lbs. Sludge No. 1 { 50 lbs. Nitrogen. 59 lbs. Phosphoric Acid. }	16·5	18·0	—	17·2	+ 2·0
26	10 tons poor cattle dung (made without cake)	20·0	18·0	—	19·0	+ 3·8
27	10 tons rich ditto. (made with cake)	28·25	21·0	—	24·6	+ 9·4

In judging of the effects of the manures, it will be desirable to have regard to the figures on each plot rather than to the average yield. There is reason to suspect that something has gone wrong with the yield recorded from the third unmanured plot. Three plots only in the whole series of over sixty gave a higher yield, and it is 50 per cent. more than was obtained from the other unmanured plots, each of which produced 12¾ cwt. of hay. Further, the manured plots immediately adjoining Plot 10 C. yielded 16¼ and 14¼ cwt. respectively. Nothing exceptional was noticed in the crop of this plot, nor can any explanation of the anomalous yield be obtained. If the yield of Plot 10 C. is discarded, and the returns from the other Plots are examined, the following conclusions would seem to be warranted. The residue of 10 cwt. basic slag has produced a distinct increase. Farmyard manure, especially when enriched by the use of oil cakes, has produced a marked increase. When the yields from Plots 10, 32 and 7 are compared, it seems probable that the residue of Sludge No. 1 on the last named plot has been responsible for a slight increase. The larger dressing of this sludge on Plot 11 has produced a distinct increase. A comparison of Plots 30, 28 and 11 would indicate that the effects of the sludge are not entirely due to the phosphates present in it. The increase might be entirely due to the nitrogen contained in the sludge, but there are no results for comparison bearing on this point, and it is reasonable to assume that both the nitrogen and phosphates have been available.

The results obtained from the other sludges at Cambridge were :—

Plot.	Yield per acre. A.	B.
	cwt.	cwt.
No. 2.	14·25	15·75
No. 3.	15·75	13·5
No. 4.	14·0	17·5
No. 5.	12·75	17·75
No. 6.	12·5	17·5
No. 7.	13·5	17·75

If these figures are compared with the yields obtained on the unmanured plots and on Plots 32 A. and B., the impression is formed that at Cambridge the sludges have been responsible for a slight increase in crop.

But here, as in the general results, it is impossible to draw definite conclusions as to the value of the residues of sewage sludge. One can only point to indications of value, and again draw attention to the fact that the season was unsuitable.

I am afraid that so far as the present series of experiments is concerned, the verdict as to the manurial value of sewage sludge must rest at—" Not proven."

T. H. Middleton.

Board of Agriculture.

Feb. 11th, 1909.

TABLE A.—Showing General Scheme of Experiments and Results, with Averages. Season 1908.

1	2		3	4	5	6	7		8		9		10		11		12		1A
No. of Plot.	Sludge.		Sulphate of Ammonia (a).	Basic Slag (b).	Lime.	Approximate cost of Artificial Manures (c).	Glasgow. West of Scotland Agricultural College.		Newcastle-on-Tyne. Armstrong College.		Leeds (d). Department of Agriculture. The University.		Cambridge. Department of Agriculture. The University.		Harpenden. Rothamsted Experimental Station.		Average (f).		No. of Plot.
							Yield per acre.	Increase or decrease of yield per acre over average of unmanured plots.	Yield per acre.	Increase or decrease of yield per acre over unmanured plot.	Yield per acre.	Increase or decrease of yield per acre over average of unmanured plots.	Yield per acre.	Increase or decrease of yield per acre over average of unmanured plots (e).	Yield per acre.	Increase or decrease of yield per acre over average of unmanured plots.	Yield per acre.	Increase or decrease of yield per acre over average of unmanured plots.	
	No.	lb.	lb.	lb.	lb.	s.	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.	cwt.	
1	7	1724	—	—	—	—	47·5	+3·7	32·5	+2·5	36·8	+1·4	15·6	+0·4	27·9	+11·1	32·1	+4·6	1
2	6	1724	—	—	—	—	43·8	0·0	20·0	−10·0	37·9	+2·5	15·0	−0·2	22·1	+5·3	27·8	+0·3	2
3	5	1724	—	—	—	—	45·7	+1·9	27·5	−2·5	35·0	−0·4	15·3	+0·1	15·7	−1·1	27·8	+0·3	3
4	4	1724	—	—	—	—	47·7	+3·9	20·0	−10·0	35·7	+0·3	15·8	+0·6	15·7	−1·1	27·0	−0·5	4
5	3	1724	—	—	—	—	45·2	+1·4	20·0	−10·0	38·2	+2·8	14·6	−0·6	20·0	+3·2	27·6	+0·1	5
6	2	1724	—	—	—	—	45·5	+1·7	25·0	−5·0	37·3	+1·9	15·0	−0·2	19·3	+2·5	28·4	+0·9	6
7	1	1724	—	—	—	—	49·3	+5·5	27·5	−2·5	36·8	+1·4	15·1	−0·1	17·1	+0·3	29·2	+1·7	7
8	1	862	—	—	—	—	45·0	+1·2	22·5	−7·5	37·1	+1·7	15·6	+0·4	16·4	−0·4	27·3	−0·2	8
9	1	862	Applied in Spring (1907)			—	45·9	+2·1	30·0	+0·0	37·9	+2·5	15·1	−0·1	16·4	−0·4	29·1	+1·6	9
10	Unmanured.				—	—	42·3	—	30·0	—	36·1	—	12·8 20·0	—	17·9	—	27·5	—	10
11	1	2586	—	—	—	—	38·6	−5·2	27·5	−2·5	35·4	0·0	17·3	+2·1	17·1	+0·3	27·2	−0·3	11
12	1	1724	100	—	—	11	39·5	−4·3	27·5	−2·5	33·9	−1·5	16·0	+0·8	15·7	−1·1	26·5	−1·0	12
13	1	1724	—	50	—	1	44·5	+0·7	27·5	−2·5	36·4	+1·0	17·0	+1·8	15·7	−1·1	28·2	+0·7	13
14	1	1724	100	50	—	12	36·4	−7·4	20·0	−10·0	35·5	+0·1	15·3	+0·1	20·0	+3·2	25·4	−2·1	14
15	—	—	—	50	—	1	36·0	−7·8	25·0	−5·0	33·2	−2·2	17·0	+1·8	22·1	+5·3	26·7	−0·8	15
16	—	—	—	100	—	2	47·3	+3·5	20·0	−10·0	32·5	−2·9	18·1	+2·9	17·1	+0·3	27·0	−0·5	16
17	—	—	100	—	—	11	43·9	+0·1	22·5	−7·5	34·3	−1·1	14·0	−1·2	15·7	−1·1	26·1	−1·4	17
18	—	—	200	—	—	22	43·6	−0·2	42·5	+12·5	35·0	−0·4	12·8	−2·4	15·7	−1·1	29·9	+2·4	18
19	—	—	100	100	—	13	48·9	+5·1	20·0	−10·0	30·9	−4·5	17·1	+1·9	17·1	+0·3	26·8	−0·7	19
20	—	—	200	100	—	24	46·6	+2·8	30·0	+0·0	32·9	−2·5	15·0	−0·2	20·0	+3·2	28·9	+1·4	20
21	—	—	200	50	—	23	46·8	+3·0	32·5	+2·5	35·4	0·0	12·8	−2·4	17·1	+0·3	28·9	+1·4	21
22	—	—	100	50	—	12	50·5	+6·7	27·5	−2·5	33·6	−1·8	15·1	−0·1	22·9	+6·1	29·9	+2·4	22
23	Unmanured.				—	—	45·2	—	—	—	34·6	—	12·8	—	15·7	—	27·1	—	23
24	—	—	—	—	—*	2	41·8	−2·0	—	—	28·2	−7·2	14·3	−0·9	19·3	+2·5	25·9	−1·6	24
25	—	—	—	—	—*	2	44·5	+0·7	—	—	31·4	−4·0	16·0	+0·8	18·6	+1·8	27·6	+0·1	25

(a) 100 lbs. Sulphate of Ammonia=20 lbs. N. (b) 100 lbs. Basic Slag=17·5 lbs. P_2O_5. (c) Cost reckoned as for Cambridge experiments. (d) All sludges applied in Spring (1907). (e) Differences between manured and average of 3 unmanured plots. (f) Differences between the manured plots and the average of 9 unmanured plots. * Plots 24 and 25 received lime at the several centres in the following quantities: Glasgow, 504 lbs lime=431 lbs. CaO; Newcastle (not stated); Leeds, 550 lbs. lime; Cambridge, lime=440 lbs. CaO; Harpenden, 60 lbs. quick-lime. † Corresponds with the figure for Plot 29 in Table.

REPORT ON THE STERILISATION OF SEWAGE EFFLUENTS.

By Dr. A. C. Houston.

CONTENTS.

It may serve as a useful introduction to this subject if I quote from one of my previous Reports* to the Commission as follows :—

"Next as regards the complete or partial sterilisation of the effluents by chemical substances. By complete sterilisation is meant the absolute destruction of all microbes, sporing and non-sporing. By partial sterilisation the death of all bacteria present as bacilli (or in coccus form) is implied, but not the death of the spores of bacteria. And for a reason presently to be explained it is of advantage to limit this a little further by saying that this partial sterilisation may be judged to be sufficient if B. Coli is destroyed.

"This distinction is important, because the difficulty of killing spores is very great, whereas bacilli (and cocci) are much more easily destroyed. Thus the thermal death point of B. Coli is about 60-65° C.; of some spores actually 120° C. And the same striking difference holds good in the main as regards chemical antiseptic substances. It is evident then that the difference in cost between the complete and partial sterilisation of an effluent would be a very material difference, and it may be questioned if the additional freedom from danger resulting from complete sterilisation would merit the extra expenditure.

"The number of spores of aerobic and anaerobic bacteria in sewage would seem to be about 100-1,000 per c.c. in the case of a total bacterial flora of 1-10 million or more. So that the spores form a relatively small proportion of the total germs in sewage. Of pathogenic spores habitually or occasionally present in sewage, B. enteritidis sporogenes, tetanus, malignant œdema and anthrax must be considered. Are we to consider that the risk of these and other sewage spores remaining in an effluent which is being discharged into a potable river is so grave that complete sterilisation is necessary? In the present state of knowledge this can hardly be said, and having regard to the almost insuperable difficulties attending complete sterilisation of effluents, to insist upon it would seem to be impracticable.

"What then would the partial sterilisation of effluents mean? It seems justifiable to conclude that the destruction of B. Coli would mean the death of the typhoid bacillus, and perhaps in general of the germs of epidemic disease. And it may be seriously questioned if the practical difficulties and the cost of such partial sterilisation is in any way out of proportion to the enormous gain in securing comparative immunity from danger. A large number of substances would seem to be capable of effecting this object at a reasonable cost, *e.g.*, ozone and chlorine compounds.

"The question what means are available for sterilising or partially sterilising sewage effluents, and what would be the cost of adopting such means, is one which should, I think, be definitely settled by further experiments.

"In the present state of knowledge, and bearing in mind what is practicable, I consider that in the case of potable rivers it would be reasonable to require that an effluent be free, or nearly so, from putrescible matter as judged by chemical standards; and be free also from the specific germs of epidemic disease, *e.g.*, B. Typhosus as judged indirectly but seemingly in safe fashion by the absence of B. Coli."

It will serve no useful purpose to include in this Report a large number of preliminary experiments, which were carried out in the laboratory, with various germicidal agents, and under various conditions.

These experiments were carried out as a guide to future work and they showed, among other things, the importance of economising the dose of germicide by prolonging the duration of contact of the liquid to be sterilised with the sterilising agent. In the past, undue importance has been attached to rapidity of action, with the result

* Provisional note on the Bacteriological qualities of crude sewage and sewage effluents and the question of standards in relation to potable and non-potable streams. Second Report of the Royal Commission on Sewage Disposal, 1902, pp. 27-28.

often, that a dose of germicide had to be recommended (to be effective) which was in excess of what was really required, which was economically impracticable, and which laboured under the serious disadvantage that the sterilised fluid still contained so much of the sterilising agent as to be a possible source of danger to animal and vegetable life.

The key to successful sterilisation on a practical scale obviously is to use the smallest amount of the germicidal agent that will kill the bacteria, and to attain this end it is equally obvious that time is required. It is true that attention to this matter entails extra capital expenditure in providing special tank accommodation, but the reduction in working cost thus obtained is so material as far to outweigh this disadvantage.

There are at present four chief methods of sterilising sewage effluents which offer some hope of success either in general or particular cases.

(1) *Heat.* This is placed first because, apart from questions of cost, it is absolutely reliable and is independent of the degree of purification of the effluent. The cost would be considerably reduced by employing a temperature of 65° C (partial sterilisation) instead of 100° C (complete sterilisation). The former temperature would suffice for the destruction of B. Coli (partial sterilisation), although the latter temperature would have to be used if, for some special reason, it were considered desirable to kill the spores of bacteria (complete sterilisation). I am not aware, however, of any practical installation run on exactly these lines, but there are a number of plants in practical operation, at the present time, which are used for softening and completely sterilising water for domestic purposes, and these are now worked in such a way that the heat of the sterilised water is used to raise the temperature of the incoming cold water, so that the liquid finally escaping from the apparatus is only a few degrees warmer than the water before treatment. No opportunity has presented itself of testing this method as there appears to be no installation treating a sewage effluent by means of heat, but the thermal death point of pathogenic bacteria being well known such tests seem almost unnecessary. The whole question is one of cost, but it is very difficult to obtain precise figures on this point. The prices given are usually contingent on a combination of favourable circumstances which may not exist in actual practice. Probably a working cost ranging from £1 to £10 per million gallons would be incurred, and it is not unlikely that the price would be nearer the latter than the former figure.

(2). *Ozone.*—Sterilisation by means of ozone is an ideal method of rendering sewage effluents innocuous, and labours under one disadvantage only, namely, that it is costly, even under favourable conditions. I have had no opportunity of testing practically its value, but the efficacy of ozone as a sterilising agent* is undisputed, and has been investigated by many competent bacteriologists. There are a number of methods for the production of ozone and bringing it into intimate relation with the sewage liquid to be sterilised. As a rule, I think, the "full value" of the ozone is not obtained, the period of contact being commonly so short that an excess of ozone has to be used to be effective. To be economically successful, the effluent must be very pure and almost free from suspended matter. The working cost per million gallons is stated variously at from £1 to £10. Probably £1 to £5 is a safe estimate, but it would be perhaps wiser to calculate the cost at from £2 10s. to £5 than from £1 to £2 10s. Initial outlay and depreciation of plant are factors of importance.

(3). *Filtration.*†—Experience has been gained, as regards the sand filtration of sewage effluents, at Hendon and at Dorking, and many analyses have also been carried out of the Leeds effluents after very rapid filtration through fine material. At all these places the results were relatively good, but actually unsatisfactory. That is, although the percentage improvement was often remarkable, the actual number of bacteria found (habitually or occasionally) in the filtrate was too high to give any assurance of the uniform safety of the process. It needs to be remembered that even the sand filtration of initially much less impure water for domestic purposes at waterworks is believed to be satisfactory only in a relative sense, inasmuch as the filters fail to eliminate *all* the bacteria of intestinal outcome present in the *raw* water before filtration.

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* That is, as regards the destruction of bacteria (*e.g.* B. Coli), present as bacilli, not as spores.

† Filtration, strictly speaking, is not a sterilisation process, but it is convenient to consider it here as the object in view is the elimination of bacteria of undesirable sort from an impure liquid.

(4) *Chlorine compounds.**—Bleaching powder, sodium hypochlorite, oxychloride, "Hermite" fluid, and Howatson's liquids, have all been tried, either in this country or abroad, with successful results. Personally, I have had most experience with oxychloride and chloros (sodium hypochlorite), particularly the latter. Without prejudice to the value of other substances, it may be desirable to base my conclusions chiefly on the results of my experience with chloros (sodium hypochlorite).

Among arguments against the sterilisation of sewage effluents are :—

(1) *That the sterilised liquid may become actually poisonous, or at all events noxious in character, as a result of the presence of the sterilising agent.*—Fortunately there are a number of germidical agents known, which at the end of the sterilisation process leave no appreciable amount of poisonous or noxious ingredient in the sterilised liquid.

(2) *That the cost may be excessive* —This, of course, entirely depends on the circumstances of the case. To sterilise a sewage effluent about to be discharged into a large volume of tidal water might, apart from questions of safeguarding shell fish, involve an unjustifiable expenditure of money. To sterilise a sewage effluent destined to be discharged into a much larger volume of river water above (*and near*) the "intake" for waterworks purposes of a waterworks authority supplying the needs of a large population would involve a cost which, from the point of view of the water consumer, might be considered almost negligible. Another argument commonly used against sterilisation is to quote the cost that would be involved in the hypothetical case of a large town ; but the cost of sterilising one gallon and one billion gallons is *proportionately* the same.

A much more serious argument against the sterilisation of sewage effluents is the fact that these do not generally include storm water, which is known to be most impure bacteriologically. The cost of sterilising more than the dry weather flow of sewage would certainly be material (about 50 per cent. extra) and it might be found quite impracticable to deal satisfactorily with sudden rushes of storm water. Moreover, it is often the case that only a portion of the storm water actually reaches the sewage works, owing to the presence of storm overflows higher up in the sewerage system. Further, a waterworks authority drawing water from an average river for waterworks purposes must usually, whether the sterilisation of sewage effluents above their "intakes" is in operation or not, adopt costly precautions to render the water palatable and safe for human consumption. In this connection it may be noted that, in the event of sterilisation of the discharged sewage being practised, the waterworks precautions need perhaps not be so costly, or, if as costly, the water supply must necessarily be safer.

(3.) *That by sterilising a sewage effluent the bacteria are destroyed which brought about its partial purification, and so the complete and final purification of the liquid may be prevented or delayed.*—Nature, however, seems to have provided for such contingencies, as the nitrifying bacteria are widely distributed and are always present in river water.

(4.) *That sterilisation is not needed in the case of properly purified effluents.*—This would be true if there were sufficiently strong grounds for assuming that the processes of sewage treatment, as ordinarily practised, destroyed the specific microbes of disease, and if sewage effluents were discharged only into non-drinking water streams or into estuaries where there were no shell-fish layings. At present, the bacteriological evidence indicates that sewage effluents are safer than crude sewage only in degree.

Practically, I think it will be admitted that, provided on public health grounds it is definitely desirable, there is no convincing argument against the sterilisation of sewage effluents, unless that of cost.

It is a very difficult matter to arrive at any absolute conclusion as regards the cheapest method of sterilising sewage effluents. In the circumstances it may perhaps suffice if I can show of any one method that it is effective at a cost which is not economically impossible.

In representing chloros (sodium hypochlorite) as one substance which can be used for this purpose, I am governed chiefly by the fact that I have had prolonged experience with it, and that it can be bought at a definite price, in a state ready for

* Various other sterilising substances have been suggested or tried. For example, bromine, iodine permanganate of potassium, peroxide of hydrogen, etc. But I am not aware of any sewage installations which use these substances for sterilisation purposes.

immediate use. There are of course, other substances (*e.g.*, chloride of lime, oxychloride, Hermite fluid, Howatson's liquids), which act in the same or a very similar way to chloros, but I do not propose in this report to attempt to thrash out their respective merits. I may say, however, that some experiments carried out at Guildford with oxychloride yielded favourable results, and (allowing for the conditions of experiment not being in all respects comparable) the results were in agreement with those previously obtained by Dr. Rideal.

As regards "chloros," the United Alkali Company undertake to supply this substance in bulk at one shilling a gallon, containing at least 10 per cent. of available chlorine. For practical purposes it may be said that for one shilling a gallon a liquid may be obtained containing 10 per cent. of available chlorine.

The results of the experiments (Series I to III Addendum) permit, I think, the following conclusions to be drawn:—

1. The amount required to sterilise a sewage effluent obviously depends on the quality of the sewage effluent and the duration of contact. Questions of light and temperature should also be taken into consideration.

2. Assuming ten hours contact and a non-putrescible sewage effluent yielding to the four hours permanganate and the albuminoid nitrogen tests less than one part and ·1 part per 100,000 parts, respectively, and containing less than three parts of suspended matter, it may be said that the proportion of chloros (containing 10 per cent. available chlorine) required for the destruction of B. coli (in 1 c.c. of effluent) varies from

1 to 100,000 to 1 to 10,000 } But between 1 to 50,000 and 1 to 25,000 would probably suffice.

The cost at 1s. a gallon would thus mean extreme prices of from 10s. to £5 per million gallons, but probably the cost would be from £1 to £2; nevertheless, I think that under specially favourable conditions the cost should not exceed £1 per million gallons.

(3) If the duration of contact was shortened to one hour it is probable that the dose would have to be increased to about 1 in 10,000, entailing a cost of £5 per million gallons.

(4) If the duration of contact was only six minutes, the approximate dose required would probably be about 1 to 2,500, at a cost of £20 per million gallons.

(5) As regards questions of practicability a working cost per million gallons of less than £1 is, I think, practicable; a cost of from £1 to £10 can hardly be entertained seriously unless it does not greatly exceed the former sum, or unless the conditions are so exceptional as to merit a large expenditure; and a cost of over £10 appears to be, in any case, out of the question.

(6) The sterilisation (as regards B. coli) of a well clarified, well oxidised, and otherwise well purified sewage effluent is thus not an impracticable measure, assuming tank accommodation of at least one hour, but preferably ten hours.

Careful experiments have been carried out with fish and the results lead me to conclude that no danger to fish life is to be apprehended, provided the dose of chloros is not greatly in excess of what is actually required for sterilisation purposes and the duration of contact is sufficiently long to exhaust most of the active part of the material.*

In the addendum which follows a detailed account is given of the chief experiments carried out as regards the sterilisation of the Hendon Ducat Filter Effluent with chloros (sodium hypochlorite). My colleague, Mr. Kershaw, was associated with me in all the practical part of the investigation.

I desire to acknowledge specially and gratefully the valuable help I have received from Dr. H. Chick and Miss Power and Miss Hartley throughout the investigation.

* I have had sustained practical experience of the sterilisation of a considerable volume of sewage effluent discharging into a sluggish fishing river. A favourite spot for anglers has been at (and just below) the point of discharge of the sterilised effluent into the river, and the good catches of fish taken afford sufficient testimony of the harmlessness of the treatment.

A. C. HOUSTON.

ADDENDUM.

Series I.—Some preliminary laboratory experiments with Chloros (Sodium hypochlorite), as regards its sterilising action on a B. coli. infected water and on the effluent from the Ducat filter at Hendon.*

Experiment I.—January 23, 1902.

(A) Sterile water, contained in a stoppered bottle, was inoculated with B. coli. and a 1 c.c. control culture made. Chloros was next added in such proportion as to correspond to 1 part of chloros in 20,000 parts of water.

(B) The procedure was the same but the proportion of chloros was as 1 to 100,000.

(C) The procedure was the same but the proportion of chloros was as 1 to 50,000.

After 24 hours 1 c.c. cultures were made from (A B and C) bottles.

The final result was that the control cultures (A, B, C) yielded B. coli. but the cultures (A, B, C), after 24 hours contact with chloros, contained no B. coli.

Experiment II.—January 25, 1902.

The procedure was nearly the same as in Experiment I., but the duration of contact was 10 hours.

(A) Sterile water contained in a stoppered bottle was inoculated with B. coli. and a 1 c.c. control culture made. Chloros was next added in such proportion as to correspond to 1 part of chloros in 100,000 parts of water.

(B) A definite amount of the Hendon Ducat effluent was placed in a stoppered bottle and a 1 c.c. control culture made. Chloros was next added in such proportions as to correspond to 1 part of chloros in 100,000 parts of effluent.

After 10 hours 1 c c. cultures were made from (A and B) bottles.

The final result was that the control cultures (A, B) yielded B. coli. but the cultures (A, B) after 10 hours contact with chloros contained no B. coli.

Experiment III.—January 28, 1902.

To two stoppered bottles (A,B) containing Hendon Ducat effluent† chloros was added in the proportion of 1 to 100,000 (A) and 1 to 50,000 (B). The duration of contact was 10 hours. After 10 hours 1 c. c. cultures were made from bottles A and B. The final result was that B. coli was isolated from A culture but not from B culture.

Experiment IV.—January 30, 1902.

This experiment was carried out on the same lines as experiment III. except that an additional bottle (C) was used which contained 1 part of chloros to 25,000 parts of effluent. The final result was as follows:—

Chloros:

$\left.\begin{array}{l}1 \text{ to } 100{,}000\\ 1 \text{ to } 50{,}000\\ 1 \text{ to } 25{,}000\end{array}\right\}$ B. coli killed in ten hours.

Experiment V.—February 4, 1902.

The conditions of experiment were the same as those described under experiment IV., and the results obtained were the same.‡

Experiment VI.—February 7, 1902.

Same remarks as experiment V.

Experiment VII.—February 13, 1902.

Same remarks as experiment V.

Experiment VIII.—February 18, 1902.

Same remarks as experiment V.

Experiment IX.—February 25, 1902.

The conditions of experiment remained the same, but the result was somewhat different, inasmuch as B. coli was not killed in bottle A. (1 to 100,000.)

Experiment X.—March 4, 1902.

Same remarks as experiment V.

Experiment XI.—March 11, 1902.

Same remarks as experiment V.

Experiment XII.—March 18, 1902.

Same remarks as experiment V.

Experiment XIII.—March 25, 1902.

Same remarks as experiment V.

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* Prepared by the United Alkali Company, Liverpool. This sample was old and contained only about one-third of the amount of available chlorine usually present in the fresh samples of chloros sent out by this firm. Dr. H. Chick estimated the amount of available chlorine to be 4·547 per cent.

† It was ascertained by experiment that this effluent contained 10,000 B. coli per c. c.

‡ Of course, in each experiment a different sample of effluent was used.

EXPERIMENT XIV.—APRIL 2, 1902.

Same remarks as experiment V.

These results may be tabulated as follow :—

Experiment.		Proportion of chloros in terms of (a) chloros ; (b) available chlorine.		Liquid experimented with.	Duration of contact.	Result (1 c.c. of liquid *after* "treatment.")
		(a)	(b)			
I.	A	1 to 20,000	1 to 440,000	B. coli infected water	24 hours	B. coli killed.
	B	1 to 100,000	1 to 2,200,000	" " "	" "	" "
	C	1 to 50,000	1 to 1,100,000	" " "	" "	" "
II.	A	1 to 100,000	1 to 2,200,000	B. coli infected water	10 hours	" "
	B	1 to 100,000	" "	Hendon Ducat Effluent	" "	" "
III.	A	1 to 100,000	" "	Hendon Ducat Effluent	10 hours	B. coli not killed.
	B	1 to 50,000	1 to 1,100,000	" " "	" "	B. coli killed.
IV.	A	1 to 100,000	1 to 2,200,000	Hendon Ducat Effluent	10 hours	B. coli killed.
	B	1 to 50,000	1 to 1,100,000	" " "	" "	" "
	C	1 to 25,000	1 to 550,000	" " "	" "	" "
V.	A	1 to 100,000	1 to 2,200,000	Hendon Ducat Effluent	10 hours	B. coli killed.
	B	1 to 50,000	1 to 1,100,000	" " "	" "	" "
	C	1 to 25,000	1 to 550,000	" " "	" "	" "
VI.	A	1 to 100,000	1 to 2,200,000	Hendon Ducat Effluent	10 hours	B. coli killed.
	B	1 to 50,000	1 to 1,100,000	" " "	" "	" "
	C	1 to 25,000	1 to 550,000	" " "	" "	" "
VII.	A	1 to 100,000	1 to 2,200,000	Hendon Ducat Effluent	10 hours	B. coli killed.
	B	1 to 50,000	1 to 1,100,000	" " "	" "	" "
	C	1 to 25,000	1 to 550,000	" " "	" "	" "
VIII.	A	1 to 100,000	1 to 2,200,000	Hendon Ducat Effluent	10 hours	B. coli killed.
	B	1 to 50,000	1 to 1,100,000	" " "	" "	" "
	C	1 to 25,000	1 to 550,000	" " "	" "	" "
IX.	A	1 to 100,000	1 to 2,200,000	Hendon Ducat Effluent	10 hours	B. coli not killed.
	B	1 to 50,000	1 to 1,100,000	" " "	" "	B. coli killed.
	C	1 to 25,000	1 to 550,000	" " "	" "	" "
X.	A	1 to 100,000	1 to 2,200,000	Hendon Ducat Effluent	10 hours	B. coli killed.
	B	1 to 50,000	1 to 1,100,000	" " "	" "	" "
	C	1 to 25,000	1 to 550,000	" " "	" "	" "
XI.	A	1 to 100,000	1 to 2,200,000	Hendon Ducat Effluent	10 hours	B. coli killed.
	B	1 to 50,000	1 to 1,100,000	" " "	" "	" "
	C	1 to 25,000	1 to 550,000	" " "	" "	" "
XII.	A	1 to 100,000	1 to 2,200,000	Hendon Ducat Effluent	10 hours	B. coli killed.
	B	1 to 50,000	1 to 1,100,000	" " "	" "	" "
	C	1 to 25,000	1 to 550,000	" " "	" "	" "
XIII.	A	1 to 100,000	1 to 2,200,000	Hendon Ducat Effluent	10 hours	B. coli killed.
	B	1 to 50,000	1 to 1,100,000	" " "	" "	" "
	C	1 to 25,000	1 to 550,000	" " "	" "	" "
XIV.	A	1 to 100,000	1 to 2,200,000	Hendon Ducat Effluent	10 hours	B. coli killed.
	B	1 to 50,000	1 to 1,100,000	" " "	" "	" "
	C	1 to 25,000	1 to 550,000	" " "	" "	" "

These experiments show conclusively that under *laboratory* conditions of experiment chloros (containing 4·55 available chlorine), even in the minute proportion of one part in 100,000 parts can kill B. coli in 1 c.c. of a satisfactory sewage effluent, provided the duration of contact is ten hours.

Series II.—Experiments carried out at Hendon, on the Sterilising action of Chloros on the Ducat filter effluent*

This series of experiments was carried out at Hendon with the Ducat Effluent.

Large stoppered bottles (A.B.) were partially filled with Effluent up to a mark on the bottles corresponding in volume to 10 litres. A known amount of chloros was next added, the bottles vigorously shaken, and, at the expiration of 6 minutes, 1 c.c. was withdrawn with a sterile pipette from each bottle and added on the spot to 100 c.c. of sterile nutrient medium (primary culture) contained in a bottle. The primary cultures were conveyed to the laboratory, placed in the incubator at 37° C. and after 48 hours incubation, examined for B. coli.

* The same sample of Chloros was used as in Series I.

EXPERIMENT I., APRIL 15, 1902.

Duration of Contact.	Proportion of Chloros.	Result.
6 Minutes - - - - - - -	1 in 10,000 A. - - - - -	B. coli not killed.
	(1 in 220,000 Av. Cl.) *	
,, - - - - - - -	,, ,, ,, B. - -	,, ,,
,, - - - - - - -	1 in 5,000 A. - - - - -	,, ,,
,, - - - - - - -	(1 in 110,000 Av. Cl.) B. - - -	,, ,,
,, - - - - - - -	1 in 2,500 A. - - - -	,, ,,
,, - - - - - - -	(1 in 55,000) Av. Cl.) B. - - -	,, ,,
,, - - - - - - -	1 in 1,250 A. - - - - -	,, ,,
,, - - - - - - -	(1 in 27,500 Av. Cl.) B. - - -	,, ,,

* Av. Cl. = Available Chlorine.

EXPERIMENT II., APRIL 16, 1902.

Duration of Contact.	Proportion of Chloros.	Result.
6 Minutes - - - - - - -	1 in 1,400 A. - - - - -	B. coli killed.
,, - - - - - - -	(1 in 30,770 Av. Cl.) B. - - -	,, ,,
,, - - - - - - -	1 in 1,200 A. - - - - -	,, ,,
,, - - - - - - -	(1 in 26,370 Av. Cl.) B. . - -	,, ,,
,, - - - - - - -	1 in 1,000 A. - - - - -	,, ,,
,, - - - - - - -	(1 in 22,000 Av. Cl.) B. - - -	,, ,,
,, - - - - - - -	1 in 800 A. - - - - -	No record.
,, - - - - - - -	(1 in 17,600 Av. Cl.) B. - - -	B. coli killed.

EXPERIMENT III., April 17, 1902.

Duration of Contact.	Proportion of Chloros.	Result.
6 Minutes - - - - - - -	1 in 1,400 A. - - - - -	B. coli killed.
,, - - - - - - -	(1 in 30,770 Av. Cl.) B. - - -	,, ,,
,, - - - - - - -	1 in 1,200 A. - - - - -	,, ,,
,, - - - - - - -	(1 in 26,370 Av. Cl.) B. - - -	,, ,,
,, - - - - - -	1 in 1,000 A. - - - - -	,, ,,
,, - - - - -	(1 in 22,000 Av. Cl.) B. - - -	,, ,,
,, - - - - - -	1 in 800 A. - - - - -	,, ,,
,, - - - -	(1 in 17,600 Av. Cl.) B. - - -	,, ,,

EXPERIMENT IV. APRIL 18th, 1902.

Duration of Contact.	Proportion of Chloros.	Result.
6 Minutes - - - - - - -	1 in 5000 A - - - - - -	B. coli killed.
,, - - - - - - -	(1 in 110,000 Av. Cl.) B.	B. coli not killed.
,, - - - - - - -	1 in 2,500 A. - - - - -	B. coli killed.
,, - - - - - - -	(1 in 55,000 Av. Cl.) B.	B. coli not killed.
,, - - - - - - -	1 in 1,250 A. - - - - -	B. coli not killed.
,, - - - - - - -	(1 in 27,500 Av. Cl.) B.	B. coli killed.
,, - - - - - - -	1 in 1,000 Av. Cl. A. - - -	B. coli killed.
,, - - - - - - -	(1 in 22,000 Av. Cl.) B.	,, ,,

EXPERIMENT V. APRIL 19TH, 1902.

Duration of Contact.	Proportion of Chloros.	Result.
6 Minutes - - - - - - -	1 in 5,000 A. - - - - -	B. coli not killed.
,, - - - - - - -	(1 in 110,000 Av. Cl.) B.	,, ,,
,, - - - - - - -	1 in 2,500 A. - - - - -	,, ,,
,, - - - - - - -	(1 in 55,000 Av. Cl.) B.	B. coli killed.
,, - - - - - - -	1 in 1,250 A. - - - - -	B. coli not killed.
,, - - - - - - -	(1 in 27,500 Av. Cl.) B.	,, ,,
,, - - - - - - -	1 in 1000 A. - - - - -	B. coli killed.
,, - - - - - - -	(1 in 22,000 Av. Cl. B.	,, ,,

EXPERIMENT VI.—APRIL 21, 1902.

Duration of Contact.	Proportion of Chloros.	Result.
6 minutes - - - - -	1 in 2,500 A. - - - - -	B. coli killed.
" - - - - - -	(1 in 55,000 Av. Cl.) B. - - -	B. coli not killed.
" - - - - - -	1 in 1,250 A. - - - - - -	B. coli killed.
" - - - - - -	(1 in 27,500 Av. Cl.) B. - - -	" "
		" "
" - - -	1 in 1,000 A. - - - - -	" "
" - - - - - -	(1 in 22,000 Av. Cl.) B. - -	" ,
" - - - - - -	1 in 800 A. - - - - - -	" "
" - - - - - -	(1 in 17,600 Av. Cl.) B. - - -	" "

These results may be summarised as follows :—

1 to 10,000 - - - -	In both of the experiments B. coli not killed.
1 to 5,000 - - - -	In 5 out of 6 instances B. coli not killed.
1 to 2,500 - - - -	In 5 out of 8 instances B. coli not killed.
1 to 1,400 - - - -	In all the four experiments B. coli killed.
1 to 1,250 - - - -	In 5 out of 8 instances B. coli not killed.
1 to 1,200 - - - -	In all the four experiments B. coli killed.
1 to 1,000 - - - -	In all the ten experiments B. coli killed.
1 to 800 - - - -	In all the five experiments B. coli killed.

The experiments seemed to indicate that from about 1 to 1,000, to 1 to 1,250 of Chloros would be required to kill B. Coli in an effluent within six minutes.

EXPERIMENT I. A.—MAY 21, 1902.

This experiment differed a little from the preceding, inasmuch as after the 6 minutes cultures had been made a portion of the liquid contained in the big 10 litre bottles was poured into smaller bottles, and these smaller bottles were tested at the expiration of 60 minutes.

Proportion of Chloros.	6 Minutes.	60 Minutes.
1 in 5,000 - - - - - - - (1 in 110,000 Av. Cl.,)	B. coli not killed - - - - -	B. coli killed
1 in 2,500 - - - - - - - (1 in 55,000 Av. Cl.)	B. coli killed - - - - - -	" "
1 in 1,250 - - - - - - - (1 in 27,500 Av. Cl.)	" " - - - - - -	" "
1 in 625 - - - - - - - (1 in 13,750 Av. Cl.)	" " - - - - - -	" "

EXPERIMENT II. A.—MAY 22, 1902.

Same as experiment I. A., but no 60 minute cultures were made.

1 in 5,000 - - - - - - - (1 in 110,000 Av. Cl.)	B. coli not killed in 6 minutes.
1 in 2,500 - - - - - - - (1 in 55,000 Av. Cl.)	B. coli killed in 6 minutes.
1 in 1,250 - - - - - - - (1 in 27,500 Av. Cl.)	B. coli killed in 6 minutes.
1 in 625 - - - - - - - (1 in 13,750 Av. Cl,)	B. coli killed in 6 minutes.

EXPERIMENT I. B.—JUNE 30, 1902.

The conditions of the experiment were the same as in experiment I. A., except that Sulphuric Acid was first added to the effluent in amount sufficient both to neutralise the alkalinity of the effluent and in each instance to combine with the chloros.

Proportion of Chloros.	6 Minutes.	60 Minutes.
1 in 10,000 - - - - - - (1 in 220,000 Av. Cl.)	B. coli not killed - - - -	B. coli killed
1 in 5,000 - - - - - - (1 in 110,000 Av. Cl.)	„ „ - - - -	„ „
1 in 2,500 - - - - - - - (1 in 55,000 Av. Cl.)	„ „ - - - -	„ „
1 in 1,250 - - - - - - - (1 in 27,500 Av. Cl.)	„ „ - - - -	„ „
1 in 625 - - - - - - - (1 in 13,750 Av. Cl.) -	„ „ - - - -	„ „

EXPERIMENT II. B. JULY 1, 1902.

In this experiment double the *neutralising* quantity of acid was added. *The combining amount was kept the same.*

Proportion of Chloros.	6 Minutes.	60 Minutes.
1 in 10,000 - - - - - - (1 in 220,000 Av. Cl.)	B. coli not killed - - - -	B. coli killed.
1 in 5,000 - - - - - - - (1 in 110,000 Av. Cl.)	„ „ - - - -	„ „
1 in 2,500 - - - - - - - (1 in 55,000 Av. Cl.)	B. coli killed - - - - -	„ „
1 in 1,250 - - - - - - - (1 in 27,500 Av. Cl.)	„ „ - - - - -	„ „

EXPERIMENT III. B. JULY 2, 1902.
Conditions same as Experiment II. B.

Proportion of Chloros.	6 Minutes.	60 Minutes.
1 in 10,000 - - - - - - (1 in 220,000 Av. Cl.	B. coli not killed - - - -	B. coli killed.
1 in 5,000 - - - - - - (1 in 110,000 Av. Cl.)	B. coli killed - - - - -	„ „
1 in 2,500 - - - - - - - (1 in 55,000 Av. Cl.)	„ „ - - - - -	„ „
1 in 625 - - - - - - - (1 in 13,750 Av. Cl.)	„ „ - - - - -	„ „

EXPERIMENT IV. B. JULY 10, 1902.
Conditions same as Experiment II. B.

Proportion of Chloros.	6 Minutes.	60 Minutes.
1 in 40,000 - - - - - - (1 in 880,000 Av. Cl.)	B. coli not killed - - - -	B. coli not killed.
1 in 20,000 - - - - - - (1 in 440,000 Av. Cl.	„ „ - - - -	B. coli killed.
1 in 10,000 - - - - - - (1 in 220,000 Av. Cl.)	„ „ - - - -	„ „
1 in 5,000 - - - - - - - 1 in 110,000 Av. Cl.	B. coli killed - - - - -	„ „
1 in 2,500 - - - - - - - (1 in 55,000 Av. Cl.	„ „ - - - - -	„ „

Experiment V. B.—July 11, 1902.

Conditions same as Experiment II. B.

Proportion of Chloros.	6 minutes.	60 minutes.
1 in 40,000 - - - - - - (1 in 880,000 Av. Cl.)	B. coli not killed - - - -	B. coli killed.
1 in 20,000 - - - - - - (1 in 440,000 Av. Cl.)	" " - - - -	" "
1 in 10,000 - - - - - - (1 in 220,000 Av. Cl.)	" " - - - -	" "
1 in 2,500 - - - - - - (1 in 55,000 Av. Cl.)	B. coli killed - - - - -	" "

Experiment VI. B.—July 14, 1902.

Conditions same as Experiment II. B.

Proportion of Chloros.	6 minutes.	60 minutes.
1 in 40,000 - - - - - - (1 in 880,000 Av. Cl.)	B. coli not killed - - - -	B. coli not killed.
1 in 20,000 - - - - - - (1 in 440,000 Av. Cl.)	" " - - - -	B. coli killed.
1 in 10,000 - - - - - - (1 in 220,000 Av. Cl.)	" " - - - -	" "
1 in 5,000 - - - - - - (1 in 110,000 Av. Cl.)	B. coli killed - - - -	" "
1 in 2,500 (1 in 55,000 Av. Cl.)	" " - - - - -	" "

Experiment VII. B.—July 15, 1902.

Conditions same as in Experiment II. B.

Proportion of Chloros.	6 minutes.	60 minutes.
1 in 40,000 - - - - - - (1 in 880,000 Av. Cl.)	B. coli not killed - - - -	B. coli killed.
1 in 20,000 - - - - - - (1 in 440,000 Av. Cl.)	" " - - - - -	" "
1 in 10,000 - - - - - - (1 in 220,000 Av. Cl.)	" " - - - - -	" "
1 in 5,000 - - - - - - (1 in 110,000 Av. Cl.)	" " - - - - -	" "
1 in 2,500 - - - - - - (1 in 55,000 Av. Cl.)	B. coli killed - - - - -	" "

Experiment I.—C.—July 16, 1902.

In this experiment a comparison was made between the sterilising action of chloros without acid and chloros with acid. The acid ($H_2 So_4$) was added in the proportion of 1 to 10,000. This amount it was considered was sufficient to overcome the alkalinity of the effluent and as well as to combine with the chloros. The duration of contact in each case was one hour.

Proportion of Chloros.	Chloros + Acid.	Chloros + 0.
1 in 40,000 - - - - - (1 in 880,000 Av. Cl.)	B. coli not killed - - - -	B. coli not killed.
1 in 20,000 - - - - - - (1 in 440,000 Av. Cl.)	" " - - - -	B. coli killed.
1 in 10,000 - - - - - - (1 in 220,000 Av. Cl.)	B. coli killed - - - - -	" "
1 in 5,000 - - - - - (1 in 110,000 Av. Cl.)	" " - - - - -	" "
1 in 2,500 - - - - - - (1 in 55,000 Av. Cl.)	" " - - - - -	" "

In this experiment, at all events, the addition of the acid seemed to possess no advantage.

EXPERIMENT II. C. JULY 17, 1902.

Conditions the same as in Experiment I. C., except that double the amount of acid was employed, and the duration of contact was only 6 minutes.

Proportion of Chloros.	Chloros + Acid.	Chloros + O.
1 in 40,000 - - - - - - (1 in 880,000 Av. Cl.)	B. coli not killed - - - -	B. coli. not killed.
1 in 20,000 - - - - - - (1 in 440,000 Av. Cl.)	" " - - - -	" "
1 in 10,000 - - - - - - (1 in 220,000 Av. Cl.)	" " - - - -	" "
1 in 5,000 - - - - - - (1 in 110,000 Av. Cl.)	" " - - - -	" "
1 in 2,500 - - - - - - (1 in 55,000 Av. Cl.)	" " - - - -	B. coli killed.

EXPERIMENT III. C. July 18, 1902.

Conditions the same as in Experiment II. C.

Proportion of Chloros.	Chloros + Acid.	Chloros + O.
1 in 10,000 - - - - - - (1 in 220,000 Av. Cl.)	B. coli not killed - - - -	B. coli not killed.
1 in 5,000 - - - - - - (1 in 110,000 Av. Cl.)	" " - - - -	" "
1 in 2,500 - - - - - - (1 in 55,000 Av. Cl.)	B. coli killed - - - - -	B. coli killed.
1 in 1,250 - - - - - - (1 in 27,500 Av. Cl.)	" " - - - - -	" "
1 in 625 - - - - - - (1 in 13,750 Av. Cl.)	" " - - - - -	" "

At this stage it appeared certain that the addition of acid in the amounts set forth in the foregoing experiments exercised no material influence in increasing the germicidal action of chloros. This being true it is permissible to summarise all the experiments in this series (II.) namely :—

Experiments I. to VI.
" " IA. to IIA.
" " IB. to VIIB.
" " IC. to IIIC.

6 Minutes Contact.

1 to 40,000 - - - -	B. coli not killed - - - -	in all 6 instances
1 to 20,000 - - -	" " - - - - -	" 6 "
1 to 10,000 - - - -	" " - - - - -	" 13 "
1 to 5,000 - - - -	" " - - - - -	in 14 out of 18 instances.
1 to 2,500 - - - -	B. coli killed - - - - -	in 14 " 21 "
1 to 1,400 - - - -	" " - - - - -	in all 4 instances.
1 to 1,250 - - - -	" " - - - - -	in 8 out of 14 "
1 to 1.200 - - - -	" " - - - - -	in all 4 instances.
1 to 1,000 - - - -	" " - - - - -	in all 10 "
1 to 800 - - - -	" " - - - - -	in all 5 ,
1 to 625 - - - -	" " - - - - -	in all 6 "

Practically speaking it may be said that 1 to 1,000 was always efficient and 1 to 2,500 killed B. coli more often than not.

60 Minutes Contact.

1 to 40,000 - - - -	B. coli not killed - - - -	in 4 out of 6 instances
1 to 20,000 - - - -	B. coli killed - - - -	in 5 out of 6 "
1 to 10,000 - - - -	" " - - - - - -	in all 9 instances.
1 to 5,000 - - - -	" " - - - - - -	in all 9 "
1 to 2,500 - - - -	" " - - - - - -	in all 10 "
1 to 1,250 - - - -	" " - - - - - -	in all 3 "
1 to 625 - - - -	" " - - - - - -	in all 3 "

It appears that 1 to 10,000 was always efficient and 1 to 20,000 satisfactory in the majority of cases. In these experiments, therefore, about ten times less chloros was required for the destruction of B. coli in an effluent when the duration of contact was 60 instead of 6 minutes.

SERIES III.—*Experiments carried out at Hendon on the sterilising action of chloros* when the Ducat filter effluent mixed with chloros was allowed to flow continuously through a tank of 100 gallons capacity.*

EXPERIMENT I.—JANUARY 20, 1902.

Preliminary Experiments as regards the germicidal action of chloros with the Ducat filter effluent at Hendon.

In this experiment the 100 gallon tank (*see* plan) was used. Mr. Kershaw was good enough to design this tank and its connections and generally was associated with me in all the practical part of the investigations. The flow of the Ducat filter effluent into the tank was at the rate of 2 pints per 9 seconds or 100 gallons per hour.

As regards the germicidal solution (8 ounces of chloros in 40 pints of water; that is 1 to 100) the rate of flow was 2 gallons per hour.

Thus the effluent was treated with chloros in the proportion of 1 part of chloros to 5,000 parts of effluent, the duration of contact being one hour.

After the experiment had been in progress for considerably over 1 hour, the effluent escaping from the outlet tube of the 100 gallon tank was tested with potassium iodide and starch. It gave a strong blue colour.

Cultivations were then made on the spot in suitable media and the precaution was of course taken of using so large a bulk of medium (100 c.c.) relative to the effluent (1c.c.) as to prevent the possibility of error arising from inhibition of growth owing to the presence in the effluent of minute traces of the germicide. The cultures were conveyed at once to the laboratory and incubated at 37° C. After two days' incubation secondary plate cultures were made from the primary broth cultures.

The result was that B. coli was found to have been killed in 1 c.c. of the effluent which had been exposed for one hour to the action of chloros (1 to 5,000)

EXPERIMENT II.—JANUARY 24, 1902.

In this experiment the procedure was the same except that the germicidal solution contained only 4 ozs. of chloros in 40 pints of water. The rate of flow remaining the same it follows that the effluent was exposed for one hour to chloros in the proportion of 1 part of chloros to 10,000 parts of effluent. After the experiment had been in progress over one hour the effluent escaping from the outlet tube of the 100 gallon tank was tested with potassium iodide and starch. It gave a distinct blue colour.

On this occasion the effluent before and after treatment with the germicide was examined quantitatively for B coli: the necessary dilutions and primary cultures being made on the spot.

The final result was that whereas the effluent before treatment contained 100,000 B. coli per c. c., after treatment with chloros (1 to 10,000; 1 hour's contact) no B. coli could be found in 1/10 c. c.

EXPERIMENT III.—FEBRUARY 4, 1902.

In this experiment the rates of flow and strength of germicidal solution were altered as follows:—

The rate of flow of the effluent into the big tank was adjusted to 2 pints in 90 seconds, or 10 gallons per hour. As the capacity of the tank was 100 gallons, a microbe entering the tank might be thought of as taking about 10 hours to escape.

The strength of the germicidal solution was 8 oz. of a one per cent. solution of chloros in 800 oz. of water (that is ·01 per cent.), and the rate of flow was adjusted to 2 oz. in 7½ minutes, or 1/10 gallon per hour.

This works out at 1 part of chloros to 1 million parts of effluent: duration of contact ten hours.

After the experiment had been running for one day primary cultures were made on the spot both of the effluent before and of the effluent after treatment.

The result was that B. coli was not killed, nor were the number of B. coli diminished by the treatment.

EXPERIMENT IV., MARCH 5, 1902.

In this experiment the rates of flow both as regards the effluent and germicidal solution were the same as in Experiment III., but the strength of germicidal solution was altered to 4 ozs. of 10 per cent. chloros in 2½ gallons of water.

This works out at 1 part of chloros to 100,000 parts of effluent: duration of contact, 10 hours.

Here, again, the result was unsatisfactory, as the number of B. coli were not reduced by the treatment.

EXPERIMENT V., MARCH 11, 1902.

This was a repetition of Experiment IV. except that the strength of the germicidal solution was increased to 8 oz. of 10 per cent. chloros in 2½ gallons.

This works out at 1 part of chloros to 50,000 parts of effluent: duration of contact, 10 hours.

Again the result was disappointing as B. coli was neither killed nor diminished in number by the treatment.

At this stage of the experiments a small settling tank was used to get rid of the suspended solids antecedent to the sterilisation process.

EXPERIMENT VI., MARCH 18, 1902.

This was a repetition of the last experiment (Experiment V.), except that the strength of the germicidal solution was increased to 16 oz. of 10 per cent. chloros in 2½ gallons of water.

This works out at 1 part of chloros to 25,000 parts of effluent: duration of contact, 10 hours.

The experiment was started on a Tuesday and ran continuously until Saturday afternoon.

On Friday and Saturday mornings 1 c.c. of the effluent after treatment was added on the spot to the primary cultures.

The result was satisfactory, inasmuch as B. coli was killed in each instance.

EXPERIMENT VII.

This experiment was started on April 1st 1902 at Hendon with such a strength of chloros and such rates of flow of germicidal solution and effluent that the proportion of chloros to effluent was as 1 to 100,000, the duration of contact being as before, 10 hours.

The next day (April 2) cultures were made from the treated effluent, but the result turned out to be unsatisfactory as B. coli was not killed by the treatment.

On this same day (April 2) the strength of chloros was altered so as to correspond to 1 part of chloros to 50,000 parts of effluent (10 hours contact).

The next day (April 3) five 1 c.c. primary cultures of the treated effluent were made on the spot, at intervals of half an hour, into suitable media, transferred to the laboratory, incubated, and subsequently examined for B. coli. The result turned out to be satisfactory inasmuch as none of the five cultures contained B. coli.

On the same day (April 3) the strength of chloros was still further increased so as to correspond to 1 part of chloros to 25,000 parts of effluent (10 hours contact).

The next day (April 4) three 1 c.c. primary cultures of the effluent after treatment were again made on the spot into suitable media and transferred to the laboratory and subsequently examined for B. coli. In each instance B. coli was found to have been destroyed by the treatment.

This experiment was very satisfactory, as it showed that chloros, even in the proportion of only 1 part of chloros to 50,000 parts of effluent may destroy B. coli provided the duration of contact is 10 hours.

* In the earlier experiments the same sample of chloros was used as in Series I. Later a sample was obtained which Dr. H. Chick found to contain 8·74 % available chlorine.

Experiment VIII.

On April 14, 1902 the Hendon experiment was re-started. At first the rates of flow and strength of chloros were so arranged that the proportion of chloros to effluent was as 1 to 100,000. As before the duration of contact was 10 hours

The next day (April 15) 1 c.c. primary cultures of the treated effluent were made on the spot at 11.15 a.m. and at 1.15 p.m. Similar cultures were made on the morning and afternoon of the following day (April 16). The final result was that from all of the cultures B. coli was isolated. On April 16 the strength of chloros was increased to 1 part of chloros to 50,000 parts of effluent.

On April 17, 18, 19, 20, and 21, 1 c.c. primary cultures of the treated effluent were made on the spot. The result was that out of a total of 10 such cultures two yielded a positive result and eight a negative result as regards B. coli.

Briefly, the experiment showed that chloros in the proportion of 1 to 100,000 was inefficient, but when the proportion was increased to 1 to 50,000 B. coli was destroyed in a majority of the samples examined. It will be understood that the duration of contact was ten hours, and that from April 14 to April 21 the treatment was continuous.

Experiment IX.

On May 21, 1902, the Hendon Experiment was re-started. The rates of flow and strength of chloros were so arranged that the proportion of chloros to effluent was 1 to 25,000. As before the duration of contact was 10 hours.

1 c.c. cultures of the treated effluent were made on the spot on the following dates :—

1902.	
May 22, 23, 24, 26, 27, 28, 29, 30, 31; June 2, 3, 4, 5, 6, 7	The results were very satisfactory as B. coli could not in any instance be isolated from 1 c.c. of the effluent after treatment with chloros (1 to 25,000, duration of contact 10 hours).
June 9	Here the result was positive but it was ascertained that some hours previous to collection of sample the flow of germicidal solution had ceased owing to the tube having become blocked up.
June 10, 11, 12, 13, 14, 16	The results were again negative in each instance.
June 17, 18	Here the results were positive; B. coli being isolated in each instance from 1 c.c. of the culture.
June 19, 20, 21	The results were again negative as regards B. coli.
June 23, 24	The results were positive as regards B. coli.

It will be understood that in Experiment IX. the experiment was continuous from May 22 to June 24.

During the period 29 1 c.c. cultures of the treated effluent were made on the spot at intervals of 24 hours or longer.

The result was that in five instances only was B. coli found to have survived the treatment.

On May 21, a sample of the effluent before treatment was submitted to examination. It contained 10,000 not 100,000 B. coli per c.c. Assuming this to be about the average number during the course of the experiment, it may be said that in 24 out of 29 instances B. coli was reduced from 10,000 per c.c. to none in 1 c.c. as a result of the treatment.

Experiment X.

On June 30th, 1902, the Hendon experiment was re-started with the same rates of flow, but the strength of chloros was altered so as to correspond to 1 part of chloros to 50,000 parts of effluent.

1 c.c. cultures of the treated effluent were made on the spot on the following dates :—

1902.	
July 1, 2, 3, 4, 5, 7, 8, 9	The results were unsatisfactory as B. coli was isolated from each of the 8 cultures.
July 10	In this instance B. coli was not recoverable.
July 11, 12, 14, 15	Here again the results were unsatisfactory as B. coli was isolated from each of the 4 cultures. Possibly the great heat prevailing at that period had something to do with the results.

Immediately after the collection of the sample on July 15th, the proportion of chloros was altered so as to correspond to 1 part of chloros to 25,000 parts of effluent.

July 16, 17, 18, 19, 21, 22, 23, 24	The results were once more satisfactory, B. coli being killed in each instance.

Experiment XI.

On August 5th, 1902, the Hendon experiment was re-started under the same conditions as in the latter part of the experiment X. (chloros 1 : 25,000) ; duration in contact 10 hours.

1 c.c. cultures of the effluent after treatment were made on the spot on the following dates.

1902.	
August 6.—Positive result.	The results were unsatisfactory as in 7 out of the 9 samples, B. coli was isolated from 1 c.c. of the effluent. Possibly the results were due to the gradual accumulation of suspended matter in the big tank and to the difficulty experienced in keeping the flow of the effluent and of germicidal solution uniform.
„ 7.—Negative „	
„ 8.—Positive „	
„ 11.— „ „	
„ 12.— „ „	
„ 13.— „ „	
„ 14.—Negative „	
„ 15.—Positive „	
„ 16.— „ „	

Experiment XII.

On November 5th, 1902, the Hendon Experiment was re-started, but a new lot of chloros (8·74 % available chlorine) was employed. Further, the big tank was divided into compartments so as to allow of cultures being made after six and sixty minutes' exposure to the germicidal solution as well as after ten hours' centact. The rates of flow and strength of germicidal solution were so arranged as to correspond to one part of chloros to 25,000 parts of effluent.

One c.c. cultures were made on the spot from the small (six minutes' contact), medium (60 minutes' contact), and big tank (ten hours' contact) on the following dates with the following results :—

Duration of Contact.

1902.	6 Minutes.	60 Minutes.	600 Minutes (10 Hours).
November 7 - - -	B. coli present - - -	B. coli present - - -	B. coli present.
8 - - -	„ „ - - -	„ „ - - -	Negative result.
10 - - -	„ „ - - -	„ „ - - -	„ „
11 - - -	„ „ - - -	„ „ - - -	„ „
12 - - -	„ „ - - -	„ „ - - -	„ „
13 - - -	„ „ - - -	„ „ - - -	„ „
14 - - -	„ „ - - -	„ „ - - -	„ „
17 - - -	„ „ - - -	„ „ - - -	Coli present.
18 - - -	„ „ - - -	„ „ - - -	Negative result.
19 - - -	„ „ - - -	„ „ - - -	Coli present.
20 - - -	„ „ - - -	„ „ - - -	„ „

At this stage a break occurred in part of the apparatus. The experiment was re-started November 25th.

November 26 - - -	B. coli present - - -	B. coli present - - -	Negative result.
27 - - -	„ „ - - -	„ „ - - -	„ „
28 - - -	„ „ - - -	„ „ - - -	„ „
December 1 - - -	„ „ - - -	„ „ - - -	„ „
2 - - -	„ „ - - -	„ „ - - -	„ „
3 - - -	„ „ - - -	„ „ - - -	„ „

On Dec. 4th, frost interfered with the progress of the experiment.

On Dec. 15th, experiment was restarted and the amount of chloros was increased to 1 part of chloros to 12,500 parts of effluent.

December 16 - - -	B. coli present - -	Negative result - -	Negative result.

Strength of chloros raised to 1 part of chloros to 6,250 parts of effluent.

December 17 - - -	B. coli present - -	Negative result - -	Negative result.

Strength of chloros raised to 1 part of chloros to 3,125 parts of effluent.

December 18 - - -	Negative result - -	Negative result - -	Negative result.

Experiment stopped and restarted on Dec. 29, the strength of chloros being 1 part of chloros to 3,125 parts of effluent.

December 30 - - -	Negative result - -	Negative result - -	Negative result.

Strength of chloros reduced to 1 part of chloros to 6,250 parts of effluent.

December 31 - - -	B. coli present - - -	B. coli present - - -	Negative result.

Experiment stopped on account of frost.

The results of this experiment seemed to show that chloros (1 to 25,000) usually killed B. coli if the duration of contact was 10 hours, but 1 hour's exposure proved insufficient. When the proportion of chloros was raised to 1 to 12,500 B. coli was killed in one hour in one instance, but in one out of two cases when the proportion was as high as 1 to 6,250 B. coli survived exposure for 1 hour to the disinfectant. To kill B. coli with 6 minutes contact about 1 to 3,125 of chloros was seemingly necessary.

The experiment shows very clearly the enormous importance of prolonged contact of the germicidal solution with the effluent if sterilisation is to be effective when using a small amount of the disinfectant.

Chloros (4·547 available chlorine).

Experiment.	Available Chlorine	Strength of Chloros.	Duration of Contact.	Result.
I.	1 in 110,000	1 to 5,000	60 minutes.	B. coli killed.
II.	1 in 220,000	1 to 10,000	"	" "
III.	1 in 22,000,000	1 to 1,000,000	10 hours	B. coli not killed.
IV.	1 in 2,200,000	1 to 100,000	"	" "
V.	1 in 1,100,000	1 to 50,000	"	" "
VI.	1 in 550,000	1 to 25,000	"	B. coli killed (two samples).
VII.	1 in 2,200,000	1 to 100,000	"	B. coli not killed.
	1 in 1,100,000	1 to 50,000	"	B. coli killed (five samples).
	1 in 550,000	1 to 25,000	"	B. coli killed (three samples).
VIII	1 in 2,200,000	1 to 100,000	"	B. coli not killed (four samples).
	1 in 1,100,000	1 to 50,000	"	B. coli killed in eight out of 10 samples.
IX.	1 in 286,000	1 to 25,000	10 hours	B. coli killed in 24 out of 29 samples.
X.	1 in 572,000	1 to 50,000	"	B. coli not killed in 12 out of 13 samples.
	1 in 286,000	1 to 25,000	"	B. coli killed (8 samples).
XI.	1 in 286,000	1 to 25,000	"	B. coli not killed (seven out of nine samples).
XII.	1 to 286,000	1 to 25,000	6 minutes	17 samples B. coli not killed.
			60 "	17 samples B. coli not killed.
			10 hours	13 out of 17 samples B. coli killed.
	1 to 143,000	1 to 12,500	6 minutes	B. coli not killed.
			60 "	B. coli killed.
			10 hours	" "
	1 to 71,500	1 to 6,250	6 minutes	B. coli not killed (two samples).
			60 "	B. coli killed (one out of two samples).
			10 hours	B. coli killed (two samples).
	1 to 35,750	1 to 3,125	6 minutes	" " " "
			60 "	" " " "
			10 hours.	" " " "

In considering these results it is to be noted that the experiments were carried out under practical conditions, and although the volume of effluent dealt with was not very great, it was quite sufficient to allow of useful conclusions being drawn.

6 *Minutes Contact.*

A short exposure of an effluent to the action of a germicidal solution like chloros is to be avoided if practically possible. Firstly because a relatively large proportion of germicide is required, and secondly because the chlorine is not used up in the process, and if discharged into a stream fish may be destroyed and vegetable growth inhibited.

Judging by the results set forth in experiment XII, 1 part of chloros (8·74% available chlorine) to 3,125 parts of effluent would be required to destroy B. coli.

60 *Minutes Contact.*

An exposure of 60 minutes would be considered by many a happy mean between 6 minutes which is undeniably too short a time and 10 hours which is possibly too long a time to be practicable in many cases. In experiment II, 1 to 10,000 of chloros (4·547% available chlorine) proved efficient. In experiment XII, 1 to 12,500 of chloros (8·74% available chlorine) was effective in one instance but in a later trial 1 to 6,250 failed to kill B coli in one out the two samples tested for this purpose.

10 *Hours Contact.*

This is the duration of contact which if practically possible is to be recommended. The advantages are that the proportion of chloros required is very small and there is no waste of material, the finally treated effluent being free from even traces of chlorine.

As the quality of the effluent, the amount of suspended matter present, and the temperature, varied from time to time, it is not surprising to find that the results were not always uniform.

One part of chloros to 1,000,000 parts of effluent may be dismissed as far too small an amount of the germicide to effect the destruction of B. coli.

The results would also seem to indicate that 1 part of chloros to 100,000 parts of effluent is too small an amount of the disinfectant. Nevertheless, under ideal conditions even this small proportion is not entirely out of the question as an effective agent. It must be remembered that the United Alkali Company claim to place chloros on the market at a very low price (about 1s. a gallon), containing *over* 10 per cent. available chlorine; and although the samples used in these experiments fell below this standard this was doubtless due to their having lost strength by keeping.* Again the Hendon Ducat effluent, although a very good one chemically, might by adequate sedimentation, or by filtration through very fine material, be brought into a condition still more amenable to sterilisation treatment.

One part of chloros to 50,000 parts of effluent would seem from the experiments to be by no means an impossible ideal.

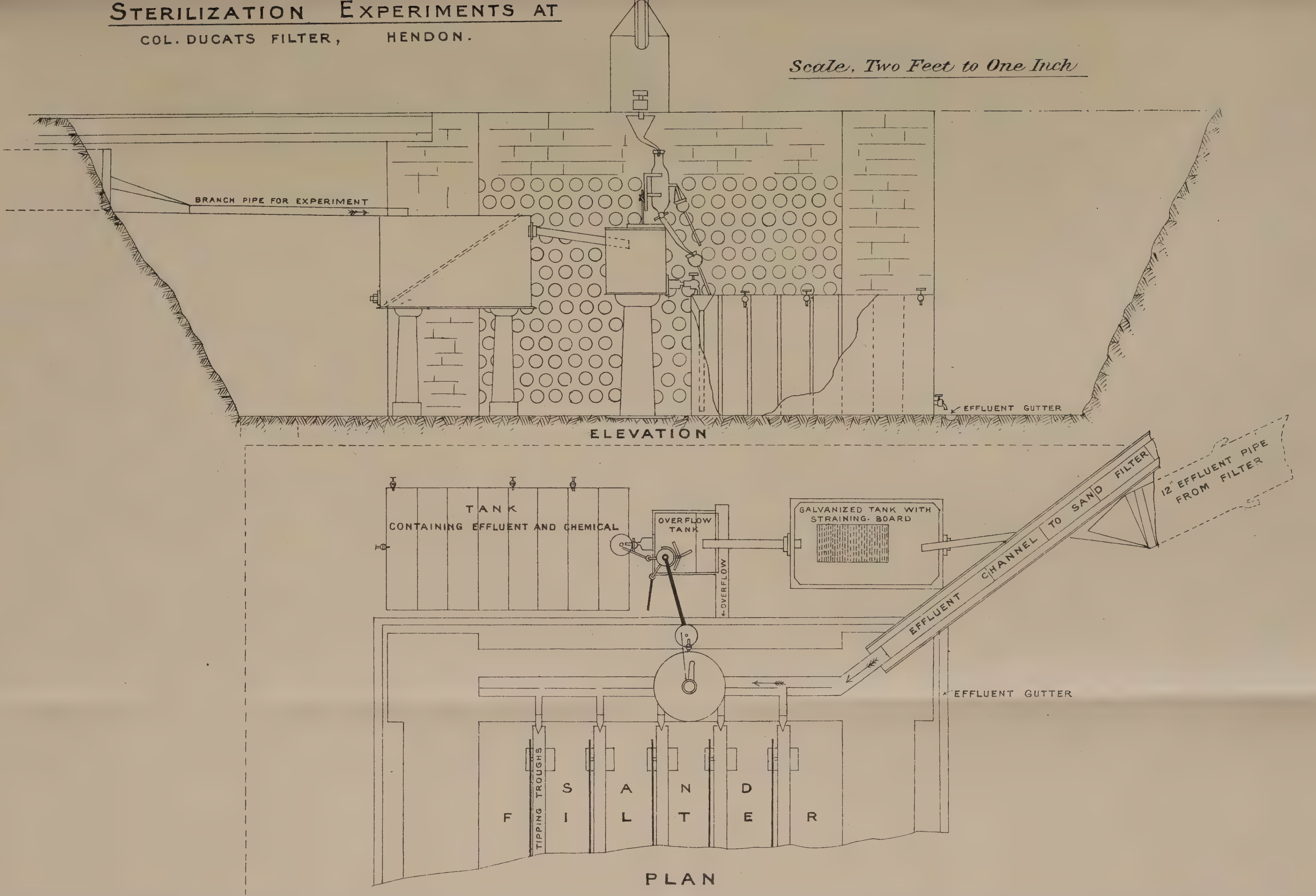
One part of chloros to 25,000 parts of effluent in the majority of instances proved effective. It is probable that with a really good sewage effluent, almost free from suspended matter, this proportion of chloros (containing 10 per cent. available chlorine) would be not only amply sufficient to kill B. coli but would provide a satisfactory margin of safety.

* Samples subsequently obtained have always contained over 10% available chlorine.

Sterilization Experiments at

Col. Ducats Filter, Hendon.

Scale, Two Feet to One Inch



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REPORT ON THE STERILISATION TREATMENT OF THE LINCOLN WATER SUPPLY BY Drs. A. C. HOUSTON and G. McGOWAN.

CONTENTS.

I.—INTRODUCTION.

A serious outbreak of enteric fever occurred at Lincoln in 1905, accounting for over 1,000 cases and involving over 120 deaths out of a population of under 52,000 persons.

In view of its bearing on the sterilization of sewage and effluents, the Commission allowed us to undertake this work at Lincoln.

The epidemic was investigated by Dr. R. J. Reece, one of the Medical Inspectors of the Local Government Board, and his exhaustive report (App. A, No. 8., pp. 81–145, Report of the Medical Officer, Local Government Board, 1905–6) merits the most careful attention.

Before dealing with Dr. Reece's report, it is important to quote from the introductory report of Mr. W. H. Power (now Sir William Power), then Medical Officer to the Local Government Board; in the first place, in relation to the particular case of Lincoln, and secondly as regards water-borne epidemics generally.

Report of the Medical Officer, Local Government Board, 1905–6, p. xvi.

"*Lincoln.*—The corporation purchased in 1871 the works of a company in whose hands the water supply of the city had rested since 1848. At the date of purchase these works comprised the Hartsholme Lake at Skillingthorpe, filter beds and pumping station at Boultham, and a service reservoir at Westgate. By the Act of 1871, which enabled the company to sell their works to the Corporation of Lincoln, the latter body were given power, in view of the increasing demands of the town, to take water, in addition to that impounded at Hartsholme, from the pike drain and from the catch-water drain near to their junction with the River Witham, within the confines of the city. And as time went on and demand for water increased, the authority supplemented their supplies by impounding water in certain ballast pits at Boultham, while at the same time extending considerably their filtration areas.

"At no time seemingly since purchase of the waterworks, has the water supply of Lincoln been deemed wholly satisfactory; and as long ago as 1885 the Medical Officer of Health, Dr. Harrison, while commenting in a special report on its inadequacy, raised serious question as to the uniform wholesomeness of the water delivered in the town. It was in reference to this report by Dr. Harrison that the Board expressed the view 'that the town council will incur grave responsibility if disease should hereafter spread in the city through preventable pollution of the water supply.

"In 1886, Dr. Airy, one of the Board's Medical Inspectors, having inspected Lincoln in the course of the 'Cholera Survey' of that year, left with the corporation a memorandum of recommendations, the first of which referred to 'the unsafe character of part of the public water supply, and the need of inquiry concerning other sources of supply.' In 1894, Dr. Wheaton, another of the Board's Medical Inspectors, met the corporation in conference, and urged that body to 'endeavour to obtain a supply of water from a source which is above suspicion for their district, in place of their present supply.

"But it was not until 1898 that the Corporation of Lincoln finally came to the determination to improve the water supply of their city; a decision which took effect in 1901, when a contract was entered into with Messrs. Chapman & Sons, of Salford, with the object of obtaining satisfactory water on the site of the existing works, by means of a deep boring into the underlying strata there. The operations in question were, however, unhappily delayed by jamming, with loss of the boring tool, and by measures consequent on this accident.

"Meanwhile the epidemic of enteric fever which is referred by Dr. Reece to the public water supply seized on the city and its neighbourhood. In the course of some six to seven months there occurred in Lincoln about 1,000 cases of the malady, an attack rate of about 19 per 1,000 and some 120 deaths."

Page XVIII.—"In their Third Report (1905) the Royal Commission on Sewage Disposal, in drawing attention to the fact that water supplies are liable to other and serious pollutions besides those which can be dealt with under the Rivers Pollution Prevention Act, go on to express the opinion that in this matter the supervision of some superior authority is desirable in the interests of public health.

"And the Commissioners recommend the establishment of a Central Water Authority exercising general superintendence over the whole country in regard to prevention of pollution of water.

"So far time has not been found by the legislature for considering and dealing with the questions thus raised by the Royal Commission. It is much to be desired, as will appear from the above histories of particular public water supplies, that time should be so found—and with as little delay as practicable. The outbreaks of enteric fever upon which I have commented suffice to indicate that in the past too little attention has been paid to possible sources of dangerous pollution, present and prospective, in the case of schemes of water supply submitted to the judgment of Parliament. So far as the Board are concerned it is the practice, when application is made to them for sanction to a loan for water supply, to hold local inquiry by one of their Inspectors, for the purpose of ensuring that the question whether the source of such supply is liable to contamination shall obtain careful consideration. Similarly it is the Board's practice, when application is made to Parliament, whether by local authority or by private company, for powers of water supply, to furnish to Parliament such information as the Board may find to be in their possession on the subject of liability of each particular water source to pollution. But, unhappily, in many instances the Board are not in possession of information adequate for determining whether or not a given source of

water supply is open to risk in the above sense; and accordingly, in view of the fever outbreaks above referred to, it becomes a question whether, antecedent to sanction by Parliament of powers of water supply sought by any company or local authority, inspection of the sources of such projected supply should not be undertaken by some responsible Government officer, whose duty it should be so to make report that the facts ascertained by him and his inferences thereon may be available to the Committee considering the Bill."

Reverting to Dr. Reece's report, we propose in the first place to outline his views as regards the cause of the epidemic.

Page 96 of Dr. Reece's Report.

Causation of the Fever.—" In endeavouring to account for the origin and spread of the fever which, in epidemic form, invaded the City of Lincoln, the Bracebridge Urban District, and New Boultham, in the circumstances that have been described, no agency can be regarded as affording a satisfactory explanation unless it be common to the three invaded areas, and of a sort capable of disseminating the malady in a fashion not inconsistent with the facts observed.

" Regarded from this point of view, unwholesome conditions of individual dwellings and their surroundings may be dismissed from consideration, as not conceivably serving to account for more than a fractional portion of the epidemic. So also with particular methods of excremental disposal, regarding which, however, there is, it may be noted, material difference in the three areas involved.

" There remains for consideration, among the agencies commonly regarded as apt to be associated, in causative fashion, with prevalence of enteric fever, milk, sewerage and drainage, and water supply.

" *Milk.*—In this instance, the investigations made with a view to ascertaining whether milk had been the vehicle of transmission of the fever lent no support to such a thesis. It was found that the first 48 cases of the disease derived their milk supply from no fewer than 32 different sources; and, throughout the whole course of the epidemic, the facts ascertained in relation with this question failed to suggest that milk played a part as a distributor of the infection, whether in Lincoln, Bracebridge, or New Boultham."

Sewerage and Drainage. — . . . . " The several facts and considerations set forth, while not inconsistent with sewerage conditions having played some part in the propagation of enteric fever in the invaded areas, do not support the view that in them is to be found the source of the epidemic, and that to them may be referred the greater or even a large share of the fever witnessed; and, indeed, the very manner of inception of the outbreak would seem to negative such an hypothesis. For its acceptance it is necessary to postulate practically simultaneous contamination of widely remote points of an extensive system of sewers with infective material, as to the origin and manner of conveyance of which it is not possible to form any reasonable conception.

" *Water Supply.*—On the other hand, the behaviour of the outbreak is consistent with a theory of water-borne infection. The occurrence of a few cases of enteric fever, widely distributed, and followed at no long interval by sharp and sudden increase of attacks, rapidly culminating in an outburst of explosive intensity, are features that have been frequently noted in association with epidemic prevalence of this disease when caused by specific pollution of a public water supply. As may be seen on reference to Table V. (p. 89), and to the map and charts that accompany this report, it was in this fashion that the fever manifested itself in this instance. Thus, following upon a case notified on the 2nd December and another notified on the 22nd December, there occurred in the course of four weeks 23 additional cases scattered widely over Lincoln; then, in the course of a single week, that ending January 28th, ensued great and sudden increase of the fever, no less than 124 cases being notified; while, in the week ending the 4th February, which formed the culminating point of the epidemic, the number of cases notified attained to 265.

" Review of the foregoing facts and consideration may reasonably be held to justify inference that the fever which affected the City of Lincoln, the Bracebridge Urban District, and New Boultham, owed its origin to specific pollution of the public water supply shared in common by these places; and that this supply was the medium whereby the infection was transmitted in the large majority of the cases during the epidemic which ensued."

Dr. Reece draws particular attention to the fact that (as in the Maidstone Epidemic of 1897) the cases of enteric fever persisted " after an implicated water had ceased to be considered operative", and in this connection he supplies a footnote which specially merits quotation (p. 100):—

" . . . . . . it deserves to be borne in mind that in all extensive outbreaks of enteric fever there is ground for suspicion that a not inconsiderable number of cases escape notification, as in the case of persons suffering from mild attack and experiencing only a feeling of malaise. Such person, going altogether untreated, and possessing as he does the power of communicating the disease in its severer forms to healthy people, is in a sense more dangerous to his fellows than the subject of a severe attack, which being recognised brings about isolation of the patient along with measures for limiting the dissemination of virus multiplied within his body. Such mild cases of enteric fever, accompanied with but minor symptoms of illness, would, during the enteric fever epidemic in Lincoln, have been peculiarly liable to have been overlooked, owing to the prevalence of influenza in that city."

Before leaving this part of the subject, we desire to call renewed attention to the grave danger to the community both of unrecognised and recognised cases of enteric fever, which, in by no means a negligible proportion of instances, may contain for a long time in their urine and fæces myriads of virulent typhoid bacilli.

In this connection we would specially refer to:—

The Goulstonian Lectures on "The Typhoid Bacillus and Typhoid Fever," by Dr. P. Horton-Smith (see *The Lancet*, March 24th, 31st and April 14th, 1900).

"Typhoid Carriers," by Drs. A. and J. C. G. Ledingham (*British Medical Journal*, January 4th, 1908, p. 15).

"Dissemination of Enteric Fever due to a 'Typhoid Carrier'" (*Lancet*, January 25th, 1908, p. 246).

Report to Home Secretary by Dr. R. W. Branthwaite, H.M. Inspector under the Inebriates Act, concerning outbreak of enteric fever at Brentry Inebriate Reformatory (Issued as a Parliamentary Paper (Cd. 3938.).

"A 'Typhoid Carrier' of Twenty-nine Years Standing," by Dr. George Dean (*British Medical Journal*, March 7th, 1908).*

In the present state of knowledge it is not too much to say that every case of enteric fever should be regarded as potentially the possible creator of a fresh epidemic, and as an unconscious agent in keeping alive the virus of a preventable disease.

In dealing with the rise and progress of the epidemic, Dr. Reece (Report, p. 89) shows that in the City of Lincoln† alone (population 48,784 in 1901), 1,006‡ cases of enteric fever were notified between 27th November, 1904, and 6th May, 1905.

During the first eight weeks (November 27th, 1904, to January 21st, 1905) the total number of notified cases was only 25.

During the next four weeks (January 22nd, 1905, to February 18th, 1905) the number actually rose to 647.

323 cases were notified during the succeeding nine weeks (February 19th, 1905, to April 22nd, 1905).

The last two weeks (April 23rd, 1905, to May 6th, 1905) furnished only 11 fresh notifications.

The epidemic may thus be said to have smouldered for eight weeks, flamed into violent activity for four weeks, persisted for another nine weeks, and then burnt itself out.

Dr. Reece further (p. 90) gives for Lincoln and district, during the above period, the number of attacks by and deaths from enteric fever, together with the attack rates and death rates, as follows:—

Estimated population	54,204
Number of attacks	1,058
Number of deaths	125
Attack rate per 1,000	19·5
Death rate per 1,000	2·31

Dr. Reece also gives an instructive table (Table VIII., p. 91) which shows:—

" . . . . . that at all ages, and for each age group, males suffered a greater incidence of attack than did females, and that the fatal incidence on males was likewise greater than on females, except in the age group 25–35 years.

It appears also that there was special incidence of attack on children and young adults, those in the age group 10–15 years being the greatest sufferers. The death-rate, however, was highest among persons between the ages of 15–35 years."

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* Since writing our report, a number of other important papers bearing on this subject have been published.

† For the sake of simplicity, the 27 and 31 cases notified in the Bracebridge Rural District (population 1,752 in 1901), and Branston Rural District (population 12,906 in 1901), are omitted.

‡ Exclusive of two cases, each of which was reported at a later date and after death.

Lastly, Dr. Reece's table of case mortality in the various age groups (Table IX., p. 92), showing "that with increasing age the liability to a fatal termination to the illness became increasingly great," is of great interest :—

Age groups.	Number of persons attacked.	Number of Deaths.	Number of Deaths per cent. of attack.
Under 5 years - - - -	84	2	2·38
5–10 - - - - - -	154	5	3·25
10–15 - - - - - -	161	13	8 07
15–25 - - - - -	281	32	11·35
25–35 - - - - - -	169	26	15·38
35–15 - - - - - -	91	17	18·68
45 and upwards - - - -	68	24	35·29
Total - - -	1,008	119	11·81

A final quotation (p. 101) from Dr. Reece's able report may be given :—

"Before closing this Report, I welcome the opportunity of expressing my appreciation of, and my thanks for, the unvarying courtesy and assistance which I experienced from the members of the corporation of Lincoln, their officers, and from many private persons. Nor can I omit a reference to the excellence of the work done in Lincoln during the epidemic. Whatever may have been the sins of commission or omission of their predecessors, the corporation, ably supported by their officers and by the citizens, in the hour of trial did their duty and dealt with the varying circumstances of the epidemic in a resolute, prompt, and efficient manner."

We desire to add to this a few words from our own particular point of view. At a moment's notice, without any real precedent to guide us, and under conditions the reverse of favourable, we were called upon to face responsibilities of no ordinary kind. Our position would have been quite untenable without the loyal support of the Corporation and its officials.

Four Appendices and three Addenda accompany Dr. Reece's report, namely :—

App. 1. Lincoln water supply (pp. 102–119).

App. 2. Sewerage and drainage (pp. 112–123).

App. 3. Administrative measures in view of the fever epidemic (pp. 123–127).

App. 4. (1.) Work of sanitary improvement carried out by the Corporation of Lincoln since Dr. Wheaton's visit in 1894; (2.) Work of sanitary nature still requiring to be done (p. 128).

Add. I. Report by Clinical Research Association on Lincoln water (pp. 129–133).

Add. II. Report by Dr. Klein on the bacteriological examination of Lincoln water (pp. 134–138).

Add. III. Reports by Drs. Houston and McGowan to the Lincoln Corporation on the Lincoln water (pp. 138–145).

Sterilisation of the Water.

Our sterilisation treatment of the Lincoln water began on February 11th, 1905, but before describing the nature of this treatment it is necessary to give a short account of the water works and of the sources of supply at that date. Since then they have both undergone considerable modification.

II.—Lincoln Water Supply.*

Sources of Supply.

There were at the time five sources of supply, viz :—

(1) The River Witham.

(2) The Pike Drain.

(3) The Catchwater Drain.

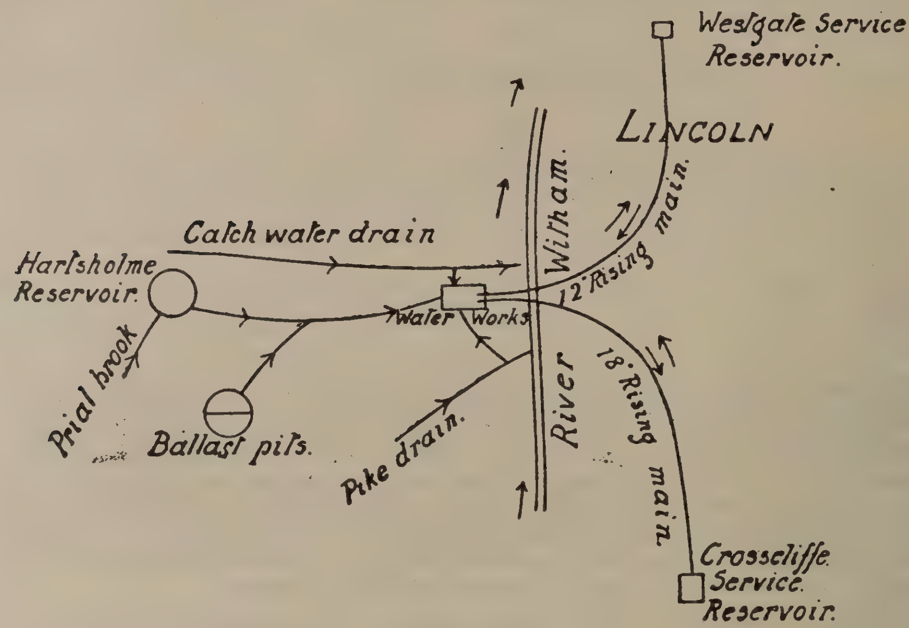
(4) Hartsholme Lake (20 million gallons capacity).

(5) Ballast Pits (25 million gallons capacity).

The ballast pit water undergoes a natural filtration process through gravel and sand, and may, we think, be regarded as a reasonably safe source of supply.

* The accompanying rough sketch is obviously not drawn to scale, but its very simplicity may help the reader.

Hartsholme Lake was liable to some degree of pollution from the Prial brook and other sources. This water contains a great deal of vegetable organic matter. Assuming subsequent careful sand filtration, however, the source of supply is free from serious objection. This water was not in use at the time of the epidemic.



The Pike and Catchwater drains discharged into the River Witham above and below the "river intake" and sometimes the flow of water in these drains was reversed, so that what was normally drain water became actually river water.

The River Witham and the Pike and Catchwater drains are all undoubtedly polluted waters, but the degree of their impurity has in our opinion been, perhaps not unnaturally, exaggerated.

With regard to the nature of the data from whose study one may arrive at a reliable opinion as to whether or not a given water is polluted, it is possible to hold decided views as to the extreme importance of topographical observations and yet to maintain a strong preference for an opinion based on the results of chemical and bacteriological analyses, interpreted in the light of local conditions. Holding this view, we think it unfortunate that indefinite and often mischievous expressions of opinion should have branded the water of the River Witham with the stigma of gross impurity. To speak of such a river as "an open sewer" verges on the ridiculous, in view of the fact that—judged by the B. coli test—it was usually at least 100,000 times less impure than sewage.

The results of our chemical and bacteriological analyses of the sources of supply are given in Tables I and II. It is well, however, to repeat here that the Hartsholme water was not in use during the period of the epidemic.

The following table briefly summarises the B. Coli results :—

TABLE I.

RESULTS, AS REGARDS THE FLAGINAC B. COLI TEST, OF THE BACTERIOLOGICAL EXAMINATION OF SAMPLES OF **Raw** (UNFILTERED) WATER, DRAWN BETWEEN FEBRUARY, 1905, AND JULY, 1906.

Description of Samples.	Negative 100 c.c. of Water.	+100 −10 c.c. of Water.	+10 −1 c.c. of Water.	+1 −·1 c.c. of Water.	+·1 −·01 c.c. of Water.	+·01 −·001 c.c. of Water.	+·001 −·0001 c.c. of Water.
Ballast Pit Water, 17 Samples.	15 Samples 88·2 %.	1 Sample 5·9 %.	1 Sample 5·9 %.				
Hartsholme Water, 13 Samples.	2 Samples 15·4 %.	1 Sample 7·7 %.	9 Samples 69·2 %.	1 Sample 7·7 %.			

TABLE I.—*continued.*

Description of Samples.	Negative 100 c.c. of Water.	+100 −10 c.c. of Water.	+10 −1 c.c. of Water.	+1 −·1 c.c. of Water.	+·1 −·01 c.c. of Water.	+·01 −·001 c.c. of Water.	+·001 −·0001 c.c. of Water.
Pike Drain Water, 12 Samples.			1 Sample 8·33 %.	7 Samples 58·3 %.	4 Samples 33·3 %.		
River Witham Water, 31 Samples.		7 Samples 22·6 %.	13 Samples 41·9 %.	9 Samples 29·0 %.	1 Sample 3·2 %.	1 Sample 3·2 %.	
Catchwater Drain Water, 11 Samples.			1 Sample 9·1 %.	7 Samples 63·6 %.	3 Samples 27·2 %.		

Bacteriological Conclusions.

It will be noted that the ballast pit water contained, in the great majority of samples, no typical B. coli, even in 100 c.c. of water.

The Hartsholme supply, viewed in the light of a water subsequently to be filtered, appears to us a water to which no serious objection could be taken, on bacteriological grounds.

The Pike Drain, Catchwater Drain, and River Witham all yielded relatively unsatisfactory results, especially the two former waters.

Nevertheless, when it is borne in mind that sewage contains about 100,000 B. coli per c.c., and that 64·5 per cent. of the samples of Witham water examined contained no B. coli in a similar quantity of water, it is obvious that the main source of the Lincoln water supply was far less impure, as judged by our tests, than was generally supposed to be the case. Some sense of proportion in these matters is desirable, because, although the use of even slightly polluted water for waterworks purposes is to be deprecated, we know of cases in which much worse water (as judged by analytical facts) is being used without apparent evil result. We think it would be fairer to attribute the Lincoln epidemic to the sudden accidental introduction of some *specific* pollution, of unknown origin, into some part of the system of water supply, rather than to the grossly and uniformly impure character of the raw sources of supply. Presumably, the beginning of 1905 was not the only period during which floods and frost and too rapid filtration occurred simultaneously. That the city escaped in the past and was stricken in 1905 is, we think, probably due to the accidental entrance into some part of the system of water supply in 1905 of some *specific** pollution, previously absent.

We are not in a position to suggest the source of the mischief, or the point at which it gained entrance to the water. The *specific* pollution may have been in the *raw* water, in the water in the filter beds, in the sand of the filter beds, in the underdrains of the filter beds, in the filter wells, or in the filtered water tank. Attention may, however, be directed to one circumstance. There was a urinal on the works, and the drain from it ran between filter beds 3 and 4 on the one side and 5 and 6 on the other, although at a lower level than the bottom of the beds. After the epidemic, when the works were being reconstructed, it was found that the drain was faulty, and it was considered that there was a possibility of the water from the faulty drain having mingled with the water in the bottom of filter bed No. 5. A trench was opened between filter beds 3 and 6 and 4 and 5, for the purpose of laying new 18″ clear water and 15″ waste water mains, and it cut across the old urinal drain. Three samples of water were drawn from this trench in March, April and May, 1906, of which the detailed analyses are given in Appendix C. II. They contained considerable quantities of ammoniacal and albuminoid nitrogen, while the figures for "oxygen absorbed" from permanganate were also high.

* It is perhaps desirable to define the word *specific*. Broadly, the excreta of healthy persons, who have never contracted water-borne disease, would be classed as objectionable, but probably *non-specific* sources of pollution. On the other hand, the excreta of persons suffering from water-borne disease (or who, as the result of past attacks, were "typhoid-carriers") would be considered highly dangerous and *specific* sources of pollution.

In the following table we give the figures of chemical analysis of a few samples of the raw waters. Those from the Ballast Pits were of much later date than the others :—

TABLE II.

	Witham Water.			No. 8. Catch-water Drain.	No. 9. Pike Drain.	Hartsholme Water.		Ballast Pit Wa	
	No. 10. Drawn about mid-way between Pike and catch-water drains.	No. 18. From left bank, 100 yards above entrance of Pike drain.	No. 34. Drawn between Pike and Catch-water drains.	Drawn at well in water-works. (This sample contains some Witham and Hart-sholme waters.)	Drawn a little above grid at Pike drain leading to works.	No. 7. Drawn at entrance to culvert.	No. 16.	No. 43. Drawn at Ballast Pit.	No. Draw Ball Pit
Drawn	February 25th, 1905.	March 23rd, 1905.	July 18th, 1905.	February 25th, 1905.	February 25th, 1905.	February 24th, 1905.	March 15th, 1905.	October 25th, 1905.	Apr 25 190
Parts per 100,000 by weight.									Filte thro paper l bei analy
Ammoniacal Nitrogen	0·001	0·003		0·001	0·004	0·001	0·001	0·002	0·0
Albuminoid Nitrogen	0·019	0·021		0·020	0·016	0·035	0·035	0·014	0·0
Nitrous Nitrogen	0·0	0·0		0·0	0·0	0·0	0·0	0·0	0·0
Nitric Nitrogen	0·433	0·300		0 300	0·152	0·055	0·072	0·040	0·1
Oxygen absorbed from dilute $\left(\frac{N}{80}\right)$ permanganate in four hours at 27° C. (80° F.)	0·158	0·231	0·476	0·194	0·123	0·284	0·298	0·053	0·0
Chlorine	4·14	3·50		3·70	3·12	2·70	2·50	2·30	2·1
Total solids (dried at about 105° C.)	49·0	59·0			25·6	16·6	18·4	12·6	12·7
Remarks	Rather cloudy, with a good deal of floccu-lent brown suspended matter. No smell. Strongly alkaline on boiling.	Very slightly opalescent, with an appre-ciable amount of suspended matter. Very slight smell (not offensive). Alkaline.	No notes were made when this sample was drawn, but the river was probably normal.	Slightly yellowish, with con-siderable suspended matter. Earthy musty smell. Alkaline.	Brownish, with con-siderable reddish-brown deposit. Slight earthy smell. Alkaline.	Yellowish and slightly turbid, with con-siderable deposit. Earthy smell. Alkaline.	Turbid and of a brown tinge, with con-siderable suspended matter. Scarcely any smell. Faintly alkaline.	Rather brownish and not very clear, with a con-siderable amount of very fine brownish solids. A distinct smell on warming (? lime), Alkaline.	Very bid, o to t deepe opera havi distu a coa of d leave the to the gr Aft pap filtra the w was ne clear, distin brow tin

The foregoing figures show that, chemically speaking, the Ballast Pit water was of very fair quality. The samples from the river Witham and the Catchwater and Pike drains, judged as raw waters, did not contain large quantities of organic matter (if we except the sample of Witham water, No. 34, drawn in July, 1905).

The water from Hartsholme Lake contains normally a very considerable amount of organic matter, but this is evidently almost entirely of vegetable origin.

Description of the Works (February, 1905).*

Hartsholme lake is situated about $1\frac{3}{4}$ miles from the waterworks, and the water flows by gravity down a closed culvert to the works, and passes on to the filter beds without requiring to be pumped.

The Ballast Pits are distant about 1 mile from the works, and the water flows by gravity down a culvert which connects with the Hartsholme culvert.

The Pike Drain and Catchwater Drain "intakes" are situated about 20 and 200 yards from the river, respectively. Although these drains discharge into the river Witham, it frequently happens that the river "backs up" to a point above both the intakes, so that virtually on these occasions the drain water ceases to exist as a source of water supply. As a matter of fact, although there is no "Witham intake" proper, a large proportion of the City's supply is derived from the Witham, via the Pike and Catchwater "intakes."

The raw water from the "drain intakes" flows by gravity into wells, from which it is pumped into a "raw water tank" which commands all the filters.

For various reasons it was found difficult to obtain accurate information as regards the volume of water entering the waterworks from the various sources of supply; we have therefore avoided giving definite figures with regard to this.

The filters are six in number, having an aggregate filtering area of 4,396 square yards.

The filtered water gravitates into a very small "pure water tank" and from thence it is pumped into two large rising mains (12 inches and 18 inches in diameter), which terminate in two uncovered service reservoirs :—Westgate (capacity, 777,000 gallons) and Crosscliffe (capacity, 1,650,000 gallons). The City is supplied directly from these two rising mains and also to some extent from a separate outflow main from Westgate service reservoir. During the day, as the consumption of water exceeds the amount being pumped from the works, the service reservoirs become partially emptied. During the night the reverse holds good and the surplus water accumulates in the service reservoirs.

The rate of filtration is governed by the number of turns given to the outlet valves from the filters.

Taking the average daily supply at about 1,800,000 gallons and the average size of the filters at 733 square yards, then the average rate of filtration would be 819, 614, 491, or 409 gallons per square yard per day, according to whether 3, 4, 5 or 6 filters were in use.

Description of the Sterilisation Treatment.

By February 9th, 1905, we were both in Lincoln, studying the local conditions, and two days later the treatment was commenced. The difficulties to be contended with were of a very serious kind, and would have been insurmountable had it not been for the willing help we received on all hands.

In the first place, we had to avoid sending into supply any water which could be regarded as injurious to health.

Secondly, as the *raw* water passed *direct* on to the filters, the much easier task of "treating" the water in storage reservoirs, antecedent to filtration, was impossible.

Thirdly, it was impossible to locate the mischief, and accordingly we had to proceed as if all the filters and the two service reservoirs were *specifically* infected, and as if the *raw* water *constantly* contained the typhoid bacillus.

Fourthly, the service reservoirs were of small capacity.

Lastly, there was no real precedent † to guide us, and we were called upon without warning, to act in a case involving the well-being of over 50,000 persons.

If, therefore, any of the measures which were adopted seem drastic, it is well to remember that during the three weeks preceding the first day of treatment (February 11th, 1905), 544 cases of typhoid fever had been notified out of a population of under 52,000 persons.

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* Since November, 1905, the works have been reconstructed under the direction of the present engineer, Mr. Neil McKechnie Barron, C E. The above description, therefore, refers to the time preceding and immediately following the epidemic.

† The circumstances pertaining to the Maidstone Epidemic in 1897 were so widely different from those associated with the Lincoln Epidemic, that Professor Woodhead's able work at Maidstone did not lessen the responsibility of our own position.

A daily diary of treatment is given in Appendix A.

The sterilising agent used was "Chloros" (an alkaline solution of sodium hypochlorite), supplied by the United Alkali Company, Liverpool. This liquid contains hypochlorite equivalent to over ten per cent. of "available chlorine" and is a powerful oxidising and germicidal agent. The circumstance of its being a liquid, miscible with water in any proportion, is of course a great advantage. We had previously found it to be very effective in the sterilisation of sewage effluents.

In the circumstances of the case it appeared necessary to continuously sterilise the *raw* water; to dose, once and for all, each filter bed in turn with the germicide; to bring the accumulated sand on the works into a safe condition; to inquire into the position and condition of urinals, etc., on the works; to advocate scavenging and patrolling operations in the neighbourhood of the "intakes"; and to treat the water in the service reservoirs.

The treatment may therefore be divided into:—

A.—*Treatment at the Waterworks.*

(*a*) Treatment of the *raw* water.
(*b*) Sectional treatment of the filter beds.
(*c*) Treatment of the accumulated sand on the works.
(*d*) Treatment of urinals, privies, etc., on the works.
(*e*) Scavenging and patrolling operations in the neighbourhood of the "intakes," etc.

B.—*Treatment of the water in the Service Reservoirs.*

A.—Treatment at the Works.

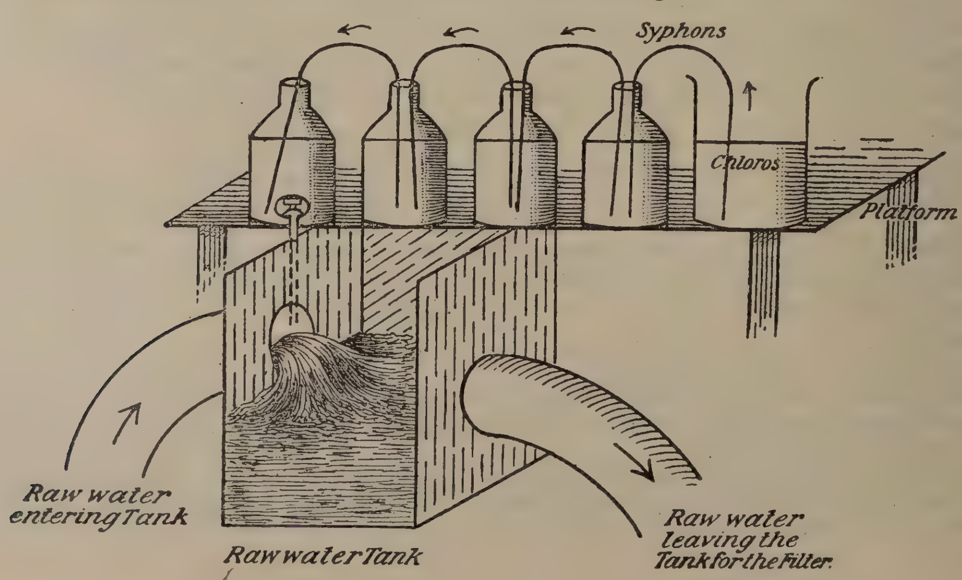
(a) *Treatment of the Raw Water.*

It will be remembered that the Hartsholme water was not in consumption at the time of the epidemic, and not much Ballast Pit Water (a relatively pure water) was being used either. In the circumstances it was felt that it was unnecessary to treat this part of the supply (the Ballast Pit Water), which reaches the Works by gravitation and is not pumped up into the "raw water tank" previously alluded to.

The treatment was therefore confined to the Pike Drain, Catchwater Drain and Witham sources of supply.

Staging was run up beside the "raw water tank" and the chloros (suitably diluted) was arranged in a series of syphon-connected jars on a platform commanding the tank. The object of having a number of these jars was to ensure a large reserve of chloros being always on hand and a fairly constant "head."

The last of the jars was provided with an earthenware tap, and the flow therefrom was so adjusted that it delivered into the tank the correct dose of the germicide, relative to the volume of water being pumped on to the filter beds. It will be seen from the diary that the initial dose was 1 of chloros in 10,000 of water, and throughout the long history of the treatment it may be said to have fluctuated between 1 in 10,000 and 1 in 1,000,000, but usually it was 1 in 100,000. The following is a rough sketch of the apparatus used, which though obviously diagrammatic and out of proportion, may nevertheless be more useful than a finished drawing.



After thorough mixing in the " raw water tank," the chloros-treated water flowed on to the filter beds. In principle, this treatment was, of course, wrong, as it interfered with or prevented the formation on the top of the sand in the filters of the " living blanket " which is considered essential to water purification. But in the absence of storage reservoirs we had no choice, and, in effect, we relied on the chloros killing the objectionable bacteria during the period that the water (several feet in depth) was detained on the top of a filter bed. The mud deposit on the top of the filter beds contained a certain amount of some compound of, or admixture with, hypochlorite, * and conceivably the surviving bacteria in passing through this deposit suffered further destruction. An interesting feature of the experiments was that, although the *undesirable* bacteria were largely destroyed, the *total* number of microbes in the filtrate was greatly increased. This, we think, was due to the multiplication of " water bacteria " in the deeper layers of the filters and in the under-drains. But the results of the treatment, chemical and bacteriological, had best be dealt with at a later stage.

(b) *Sectional Treatment of the Filter Beds.*

At a very early stage of the treatment we found that no blue colouration could be obtained by the addition of potassium iodide and starch to the water *after* filtration, although the water on the top of the sand on the filters gave a strong positive result. As we had no means of knowing whether the interior of the filters and the under-drains were free from infection, it was decided to treat each filter in turn with a *strong* dose of chloros until a distinct blue reaction was obtained in the filtrate, then to shut the outlet valve for several hours, and thereafter to allow the water to pass into supply very slowly. This special treatment, which entailed considerable anxiety, was commenced on February 18th and completed on February 21st. It is described in the daily diary of treatment.

(c) *Treatment of the accumulated sand on the works.*

We thought it desirable, as an extra precaution, to treat all the heaps of sand on the works with dilute chloros (*see* daily diary of treatment).

(d) *Treatment of urinals, privies, etc., on the works.*

Here again we considered it advisable to use chloros pretty freely, and we also added it to the water in the Bracebridge ditch adjoining the works.

(e) *Scavenging and patrolling operations in the neighbourhood of the " intakes," etc.*

Although this may seem at first sight to have no connection with the sterilisation treatment, it was obvious to us that the greater the care taken to guard against "nuisance" along the banks of the Pike and Catchwater drains and the River Witham, the sooner should we be in a position to consider the possibility of reducing the dose of chloros at the works. We saw, in the neighbourhood of the works, quite enough to lead us to impress on those in authority the necessity for paying strict attention to this matter.

B.—Treatment of the Water in the Service Reservoirs.

The first treatment of the water in Crosscliffe service reservoir was on February 11th, 1905, and the treatment was continued at intervals of a few days.

The water in Westgate service reservoir was first treated on February 12th, and thereafter on the dates set forth in the daily diary of treatment.

The method of treatment was very simple. Carboys of chloros were placed in a boat and the liquid was allowed to siphon very slowly over the edge of the boat into the water. By means of a long rope the boat was dragged to and fro and round about the reservoir, so as to distribute the disinfectant as uniformly as was practicable under the circumstances.

* Thus, on several occasions the " skin " above the surface sand, the surface sand itself, and the sand at different depths below the surface (*e.g.*, 9 and 18 inches) were tested quantitatively for hypochlorite by acidifying with dilute sulphuric acid, adding potassic iodide and starch, and titrating with thiosulphate. In every case the surface sand, in virtue of its adhering mud, was found to contain more hypochlorite (?) than the sand lower down in the bed. Probably, at the actual time of drawing the samples, there was still more hypochlorite in the skin than in the surface sand, but as a day usually intervened between the drawing and the testing, the greater amount of organic matter in the skin no doubt reduced much of the hypochlorite originally held up in it (*cf.* Appendix C. VII).

The treated water was "held up" in the reservoir for as long a time as was possible and, practically speaking, no water was ever allowed to go into supply which gave a blue coloration with potassium iodide and starch.

We desire very specially and gratefully to acknowledge our indebtedness to Mr. Denison B. Byles, B.Sc., F.I.C., who took charge of the treatment at Lincoln for us from March 1st to July 31st, 1905. He rendered us the most valuable assistance and succeeded, often under trying circumstances, in overcoming obstacles in connection with the sterilisation treatment which were of a serious kind. We wish also to express our great gratitude to our assistants, Mr. R. B. Floris, F.I.C., Mr. E. H. Richards, B.Sc., Mr. A. C. Carter, F.I.C., Miss Power, and Miss Hartley, for their able help during the sterilisation treatment.

(1).—Effect of the Treatment.

(a) *Main Tap Samples.*

In the boiler-house at the works there is a tap supplied with water from the rising main; this tap was used for drawing samples representative of the water passing to the consumers. In judging the effect of the sterilisation treatment, we placed chief reliance on the B. coli test, because a dose of a germicidal agent sufficient to destroy B. coli is more than sufficient to destroy the typhoid bacillus.

B. coli (*flaginac*) test.—The first five samples, collected on February 12th, 13th, 14th, 15th and 17th, 1905, all contained flaginac B. coli. The next two samples (March 4th and 9th) yielded negative results, but a sample collected on the 10th gave positive results. Then followed twelve consecutive samples (March 13th to 26th) containing no typical B. coli in 100 c.c. A sample collected on March 27th contained typical B. coli in 100 c.c. Again there was a run of eleven negative results (March 28th to April 11th), next a sample containing flaginac B. coli in 10 c.c., followed by a succession of 18 samples (April 13th to May 8th) containing no flaginac B. coli in 100 c.c. Two positive results occurred on the 9th and 23rd of May, but excepting these, 21 samples yielded negative results between May 10th and June 6th. Between June 15th and August 29th, 22 samples were collected and the results were less satisfactory, as 8 samples yielded positive results. Then there was another satisfactory period (August 30th to November 6th), during which 21 samples were collected, only one of which contained flaginac B. coli in 100 c.c. of water.

Between November 8th and December 12th the results were far from satisfactory, practically all the samples containing flaginac B. coli in 100, 10, 1 or ·1 c.c. of water. The last eleven samples collected in 1905, however, contained, with one exception, no flaginac B. coli.

Only two out of the first seven samples collected in January, 1906, yielded negative results, but seventy consecutive samples collected between January 12th and August 24th, 1906, contained no flaginac B. coli in 100 c.c. of water. The thirty-one samples collected between September 28th, 1906, and January 14th, 1907, were in many cases far from satisfactory, and sixteen of them contained flaginac B. coli in 100, 10 or 1 c.c. of water. The fourteen samples collected from January 17th to February 28th, 1907, were satisfactory, only one of them yielding positive results.

More striking, perhaps, than the general results were the periods during which an unbroken run of negative results occurred, and there can be little doubt, we think, that under more favourable conditions it would have been possible to have sent into supply a water *invariably* containing no B. coli even in 100 c.c. of water. But the practical difficulties at Lincoln were many. For example, complaints as to the taste of the water caused us often to reduce the dose below the point which we should otherwise have insisted on, and we have already pointed out that the absence of storage reservoirs, antecedent to filtration, made the task of sterilization a particularly difficult one.

Unfortunately we have practically no data of our own, enabling us to say what the bacteriological condition of the filtered water was, prior to our treatment. We only examined one sample, on February 11th, which contained typical B. coli in 10 c.c. of water. Reference to Dr. Reece's report (pp. 129–134) shows that the Clinical Research Association found coli-like microbes in ·2 c.c. and typical B. coli in 1 c.c. in three samples of filtered water examined, and Dr. Klein found typical B. coli in 1 c.c. of the

filtered water. Having regard to the fact that the *raw* water was delivered on to the filters without any preliminary storage, to the rate of filtration, and to the sources of supply, we think it not unlikely that previous to our treatment the filtered water did contain B. coli in 10 c.c., or 1 c.c. (perhaps even ·1 c.c.) of water, occasionally if not frequently.

Total number of bacteria.—As already indicated, a remarkable feature of the sterilisation treatment was that, instead of the bacteria in the filtrate being diminished *in number*, they were greatly increased. It is no exaggeration to say that the filtered water, instead of containing considerably under 100 microbes per c.c. (gelatine at 20° C.). contained often over 1,000.

Taking the first fifty *consecutive* samples (March 24th to June 6th, 1905) in which both the number in gelatine at 20° C. and in agar at 37° C. were determined, the averages work out at 936 and 16, respectively, per cubic centimetre.

These results may, we think, be attributed to the chloros being practically exhausted before it got far into the filter ; to the defective "skin" on the filter during the treatment ; and to the chloros possibly changing the organic matter in the water into a state more suitable for bacterial life. Consequently, the bacteria in the interior of the filter and in the under-drains found, as we think, the conditions favourable for multiplication. The chemical results, indeed, support this view, for undoubtedly one effect of the treatment of an organic mud with "chlorosed" water is to dissolve some of the organic matter.

We have had a somewhat similar experience with sewage filters at Guildford.* At that place two filters of coarse material, alike in every respect, treated the one (a) septic tank liquor which had received varying doses of "Oxychloride" solution,† the other (b) septic liquor without addition of "Oxychloride." Although the effluent from the former filter (a) usually contained the fewest number of microbes, when the amount of oxychloride added was sufficient to kill B. coli in the septic liquor, the *total* number of microbes in the *filtrate* from (a) exceeded those in the filtrate from (b).

Another point to be noted in regard to the treatment at Lincoln was that the microbes growing in agar at 37° C. were, relatively speaking, very few in relation to the number growing in gelatine at 20° C. In point of fact, most of the microbes were "water bacteria" of quite harmless sort.

(b) *Separate Filter Wells and Pure Water Tank.*

Between February 19th and March 31st, 1905, 33 samples were examined. Of these, 1 sample contained flaginac B. coli in 10 c.c. ; 11 samples contained flaginac B. coli in 100 but not in 10 c.c. ; and 21 samples contained *no* flaginac B. coli even in 100 c.c. of water.

(c) *Service Reservoirs.*

Thirty-five samples were examined from Crosscliffe Service Reservoir. At first the results were remarkably successful,the first 17 samples (February 12th to May 5th, 1905) containing no flaginac B. coli even in 100 c.c. of water. But when the warm and bright sunny weather set in (May 12th to July 6th, 1905), the results were much less favourable. The last six samples, however, collected between July 10th and 17th, were entirely satisfactory.

Thirty-four samples were collected from Westgate Service Reservoir. The first ten samples contained no flaginac B. coli in 100 c.c. of water, the next two samples yielded positive results and the next three negative results. Then followed (as in the case of Crosscliffe Reservoir) a period from May 3rd to July 7th, 1905, when the results deteriorated to a considerable extent. Of the last five samples, however, collected between the 10th and 14th of July, only one yielded positive results.

Beyond all question a dose of chloros which, in the colder and duller months of the year, was completely successful, failed altogether when the weather became warm and sunny.

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* Cf. Report upon the "Oxychloride" experiment at Guildford, by Mr. A. C. Carter ; this Appendix, p. 167.

† This, too, is a solution of sodium hypochlorite.

Nevertheless, this circumstance seems to be inadequate to explain fully the falling off in the results, especially in the case of Westgate Reservoir. The service reservoirs are supplied with filtered water from the works, and the results at the works during this period were relatively satisfactory, so that, even if no treatment of the water in the service reservoirs had been in operation, better results might have been anticipated from reservoir samples. The reservoirs are uncovered; Crosscliffe Reservoir abuts on a public road, and the surroundings of Westgate Reservoir are also unsatisfactory. These facts should be borne in mind, even though it is doubtful if they afford sufficient explanation of the observed results.

It is worth noting that vegetable growths had in past years given rise to a great deal of trouble in these two uncovered service reservoirs. During 1905, as a result of the sterilisation treatment, no such trouble was experienced.

(d) *Taps throughout the Town.*

These samples were collected from house taps throughout the area of supply, and in many cases were from houses which had been invaded by enteric fever. Out of a total of 144 samples, none contained flaginac B. coli in 10 c.c. of water, and 129 (89·6 per cent.) did not contain this microbe even in 100 c.c. of water. Except in two instances, whenever a sample failed to yield completely negative (that is, completely satisfactory) results, further samples from the same tap were examined until a negative result was obtained.

These results we think are highly satisfactory, especially in view of the fact that 100 c.c. is a relatively large volume of water to submit to cultural tests.

Chemical Analysis of the Treated Water.

Between February 14th and December 31st, 1905, 24 main tap samples from the tap in the boiler-house were examined chemically; in 1906, 12 samples; in 1907, 10 samples; and in 1908 (to end of August), 8 samples. These were nearly always clear and bright, but with a slight yellowish to brownish tint, and they contained either no visible matter in suspension, or—excepting in the case of one or two samples—only very minute quantities. As has been stated elsewhere, those samples—especially the later ones—were often free from either smell or taste; but in the earlier stages of the treatment, more particularly, they had more or less of a mawkish taste and a spent bleach odour.

Out of 12 samples tested, none showed any reaction on the day of analysis with iodide of potassium and starch solution; while out of 24 tested with iodide, starch, and dilute acid, 3 showed a distinct lilac colour and 8 others gave a slight tint.

The detailed figures of analysis are printed in Appendix C. I., but the following give a fair idea of the chemical composition of the treated water (the figures in brackets indicate the number of estimations in each case):—

Parts per 100,000.

	Average.	
Year 1905.		
Ammoniacal Nitrogen (0·002 to 0·016)*	0·005*	(24)
Albuminoid ,, (0·009 to 0·025)	0·016	(24)
Nitric ,, (Trace to 0·44)	0·18	(23)
"Oxygen absorbed" from $\frac{N}{80}$ permanganate in 4 hours at 27° C. (80° F.) (0·12 to 0·25)	0·13	(24)
Chlorine (as chlorides) (3·00 to 5·46)	3·83	(18)
Year 1906.		
Ammoniacal Nitrogen (0·001 to 0·010)	0·003	(12)
Albuminoid ,, (0·012 to 0·024)	0·018	(12)
Nitric ,, (0·01 to 0·59)	0·34	(12)
"Oxygen absorbed" in 4 hours (0·11 to 0·21)	0·17	(12)
Chlorine (2·75 to 3·74)	3·33	(10)

* Or, excluding two samples, which gave the relatively high figures 0·015 and 0·016, the ammoniacal nitrogen varied from 0·002 to 0·006, the average being 0·003.

Year 1907.

Ammoniacal Nitrogen	(0·001 to 0·003)	0·002	(10)
Albuminoid ,,	(0·011 to 0·026)	0·016	(10)
Nitric ,,	(0·12 to 0·48)	0·28	(10)
"Oxygen absorbed" in 4 hours	(0·11 to 0·28)	0·16	(10)
Chlorine	(2·81 to 3·68)	3·17	(10)

Year 1908 (to end of August).

Ammoniacal Nitrogen	(0·001 to 0·003)	0·002	(8)
Albuminoid ,,	(0·008 to 0·017)	0·012	(8)
Nitric ,,	(0·16 to 0·32)	0·24	(8)
"Oxygen absorbed" in 4 hours	(0·08 to 0·19)	0·14	(8)
Chlorine	(2·53 to 3·27)	3·03	(8)

It will thus be seen that, from a chemical point of view, the treated water gave—for a drinking water—very high figures for albuminoid nitrogen and for "oxygen absorbed" from permanganate, no doubt materially higher than would have been the case had the water been filtered without the previous addition of chloros. Since, however, only a very few samples of the raw waters were examined chemically, it is impossible to make anything like an accurate comparison between these and the treated water, as regards dissolved organic matter. The natural tendency of the (alkaline) chloros is to dissolve some of the organic matter present in the suspended solids of the raw waters and in the mud on the top of the sand beds, besides interfering to some extent with the formation of a "skin" upon the filter.

The average figures for the different years are fairly even, but the individual samples necessarily varied to a considerable extent among each other, according to the *proportions* of the different waters entering into the general supply at any one time. The Witham water is hard, while the waters from Hartsholme and the Ballast Pits are fairly soft.

Of main tap samples throughout the area of supply, only three (Nos. 12, 13, and 25) were examined chemically (in March and April, 1905), and these did not differ materially from the boiler-house tap samples drawn about the same time.

(2) *Potability of the Treated Water.*

There was thus every reason to suppose that the treatment which has just been described rendered the water usually (if not always) innocuous, so far as the complete (or almost complete) absence of disease-producing germs was concerned. A secondary result of the treatment, however, was to impart to the water a slight mawkish smell and taste, which varied more or less according to the dose of chloros, the amount of organic matter in the raw water, and the state of the sand filter beds as regards deposited mud, which necessarily contained a certain amount of organic matter. Although we are not in a position to prove the point, there can be little doubt that this slight taste and smell (which were sometimes quite inappreciable, but sometimes distinctly marked) were mainly due to the presence of minute quantities of compounds produced by the action of the *alkaline* solution of chloros on the organic matters present.

A large proportion of the inhabitants of Lincoln, already suspicious of the water on other grounds, objected strongly to the "spent bleach" taste and smell of the treated water and refused to drink it. We understand, however, that as time went on, this reluctance to use the water progressively diminished.

Such objections on the part of consumers, though perhaps not altogether reasonable, are not at all surprising, the senses of taste and smell being so extraordinarily acute. The subject is thus a difficult one for us to deal with, in all the circumstances of the case.

It has already been pointed out that the dose of chloros varied from one in 10,000 to one in 1,000,000, but usually it was one in 100,000. Further, that the "active" *

* This more or less empirical term "active" is meant to indicate a treated water which gives a blue colour on the addition of solutions of potassic iodide and starch, *without* the addition of dilute sulphuric acid.

part of the chloros was all used up (or practically so) in passing through the filter beds. How far this is true may be judged from the following statement:—

Chloros, diluted 100,000 times, yields a strong blue colour, and diluted 1,000,000 times a faint blue colour on the addition of solutions of potassium iodide and starch, *without* acid. Yet the filtered water going into supply practically never gave a blue colour with these reagents.*

If one part of chloros be mixed with 10,000 times its volume of water, and the mixture be drunk immediately, the liquid has a pleasant, slightly tart taste. Had such a mixture in the fresh unaltered condition been sent into supply, we doubt whether any serious objections as regards taste or smell would have been raised.

Sometimes the taste of the treated water was inappreciable, at other times it was barely noticeable, while occasionally it was quite distinct. In the last case, usually (but not always) the increase of taste was associated with the use of a stronger dose of chloros, rendered necessary by one reason or another, *e.g.*, by the occurrence of floods. There seemed to be a certain amount of evidence in favour of the view that the taste might become cumulative in character without any variation in the dose, and certainly, when objections were raised to the taste of the water, a marked diminution of dose was often only very slowly effective in entirely removing the cause for complaint. Perhaps the explanation is to be found in the accumulation of mud on the top of the sand in the filter beds. This mud was always found to contain some compound of chlorine which was decomposed on the addition of acid, as shown by the colour reaction on subsequently adding iodide and starch.

Excluding the worst periods, we think that the great majority of people drinking the water would never have noticed any objectionable taste, had they been unaware that the water was being chemically treated. Moreover, even when the taste was at its strongest, the water was still, in our opinion, innocuous.

It was supposed at one time that the water caused colic, conjunctivitis, and various other human ailments ; that horses, cattle, and dogs would not drink it, or, drinking it, suffered in consequence ; that it extracted an abnormal amount of tannin from tea and gave a nauseous taste to cooked vegetables ; and that it could not with safety be used for the watering of plants.

These contentions, in the main unsupported by reliable facts, arose primarily from an irreconcilable distrust of Witham water, and secondarily from a rooted antipathy to any form of chemical treatment.

Even if the taste of the water had been uniformly unpleasant, we should still have felt justified in advocating the treatment, having regard to all the circumstances of the case.

Dr. Reece, in his report (p. 117), deals with the question of taste, and says that—

> " When the water was hot or cold, this smell and taste were not markedly appreciable, but when the water was merely warm, the odour given off could not fail to be detected by persons having *ordinary* sense of smell. After some weeks of treatment, either on account of the organic matter present in the filter beds being used up, oxidised, or on account of the lesser quantity of chloros used, the smell and taste became less, and in the first week of May I could not detect it.
> . . . . "
>
> " Nevertheless, although to the senses of sight, smell, and taste the water compared favourably with the waters supplied in many places from upland moorland sources, the people of Lincoln, accustomed to a tasteless water, and having the knowledge that the water had been treated with ' chemicals ', refused in many instances to drink it."

The Practical Bearing of the Experiments at Lincoln on the Question of Future Procedure as Regards the Sterilisation of Water.

We may say at the outset that we are not in favour of the use of Chloros, or any other chemical substance known to us, for the sterilisation of water under *ordinary* conditions and as a *routine* measure.† But under exceptional circumstances, such as

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* As is well known, a blue colour is also obtained on the addition of solutions of potassic iodide and starch to very dilute solutions of nitrite, provided the mixture be acidified with dilute sulphuric acid ; but no colour is produced in the absence of acid.

† An exception should, apart from economic considerations, be made in favour of ozone, which is known to be an effective germicide and is seemingly absolutely free from any source of reasonable objection.

those which arose at Lincoln, we think our results and experience fully justify us in recommending strongly a similar kind of treatment to that which we ourselves adopted.

In the absence of very warm and sunny weather, and with large storage and service reservoirs, the treatment would be comparatively simple. In such a case we should recommend the immediate treatment of the water in the storage and service reservoirs. If the service reservoirs were small and covered, the carrying out of the treatment might be difficult, perhaps almost impossible. But water in storage reservoirs can easily be treated, by means of boats or rafts rowed to and fro, from which the chloros* is sprayed or syphoned. The dose required would vary with the organic quality of the water, but in most cases a dose of from 1 in 10,000 to 1 in 100,000 would suffice. 1 in 100,000 will be found effective in the case of a fairly pure water. It is very important to secure good distribution, and in effect this means that a great deal of patience must be exercised, and the duration of the experiment extended over as many hours as is reasonably practicable. As to how often the dose should be repeated, this depends so much on the particular circumstances of the case that no general rule can be suggested.

In most cases the primary dose should err on the side of being too strong, the subsequent treatment tailing off, as it were, according to the particular needs of the case. Once the general body of water in the storage reservoir has been effectively sterilised, it may be desirable afterwards to treat only the water entering the reservoir.

When the service reservoirs are uncovered, they may be treated in the same way as the storage reservoirs, but here it is most desirable to hold back the water from supply as long after the treatment as is possible, so as to exhaust the "active" part of the sterilising material. It is also most important to avoid using more of the substance than is necessary to prove effectual as a bactericidal agent.

As regards the filter beds, we feel some doubt in venturing on any recommendations. The case of Lincoln was peculiar, and although we took drastic steps there, a similar procedure might not be applicable in other cases.

It must not be forgotten that, by sterilising the filtering material with its "protective blanket," the normal working of a filter is destroyed, or at least embarrassed. On the whole we consider that, provided it were possible to sterilise adequately the water in the storage reservoirs, considerable hesitation should be felt before interfering with the integrity of the sand filters.

In warm, sunny weather the treatment of open reservoirs should preferably be carried out after the sun has set. But the extra dose of chloros, which we found to be necessary in the summer, was probably also dependent on other factors, *e.g.*, the increased temperature of the water.

In conclusion, while we feel that it would not be justifiable to offer too precise advice on a subject which is governed so largely by local considerations, we are quite confident as to the safety and expediency of the sterilisation of water under the circumstances pertaining to a typhoid epidemic.

A. C. HOUSTON.
GEORGE McGOWAN.

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* Bleaching powder, Howatson's solutions, Hermite fluid, "Oxychloride," etc., act in a very similar way to chloros. We prefer to base our conclusions on the results of the use of the substance of which our own experience has been greatest, without prejudice to the value of other germicides. We may, however, add that we obtained satisfactory results at Guildford with "Oxychloride."

APPENDIX A.

DAILY DIARY OF THE "TREATMENT" OF LINCOLN WATER WITH CHLOROS (SODIUM HYPOCHLORITE).

Date.	Treatment of the Raw Waters at the Works.	Treatment of Crosscliffe Reservoir Water.	Treatment of Westgate Reservoir Water.	Additional Notes.
1905. February 11th - -	Treatment commenced 9.45 a.m. The sodium hypochlorite solution was run continuously (day and night) into the small tank (see figure in text) into which the raw waters (Witham, Pike drain, and Catchwater drain waters) are pumped by means of a Worthington pump so as to allow the mixed raw waters to flow by gravitation on to the filter beds. It was estimated that on the average about 1,800,000 gallons of water per 24 hours would require to be treated, and the flow of sodium hypochlorite solution was adjusted to 7·5 gallons per hour (180 gallons per 24 hours). The proportion of sodium hypochlorite solution to raw water was thus 1 to 10,000. At this date the ballast pit water was flowing by *gravitation* into No. 1 filter bed and would largely escape treatment. Sometimes, however, there is a "backing" of the water in the pipes supplying the other filter beds, which would allow some treated water to mix with the ballast water. The ballast water being a very pure water, we felt fully justified in regarding it as safe for domestic use without treatment. Shortly after starting the treatment tests were made with potassium iodide and starch solutions of the water from all the filter wells, from the filtered water tank, and from a tap in the works in connection with a rising main. At first these tests were made every few minutes, later every hour, and still later one or more times daily. To describe in detail the results of these tests would seem to be unnecessary. It may be said that throughout the whole course of the treatment the filtered water passing into consumption either gave no blue colour with these reagents or only the faintest trace of colour.† A gold fish was placed in a pail containing some of the filtered water and fitted with a detachable wire gauge (½-inch mesh) cover. The pail was submerged in the filtered water tank to show that none of the water passing into consumption contained more than negligible traces of the agent used for sterilisation purpose in the active state. The test is a delicate one, as fish are extremely sensitive to minute doses of fresh sodium hypochlorite. Once a week a new fish was substituted for the old one for purely dietetic reasons. The fish were quite unaffected by the treatment. *NOTE.*—A quantity of clean limestone in small pieces was put into the filtered water tank before treatment began, with the idea of absorbing any traces of free chlorine, or of acid (which at one time there had been an idea of using along with the chloros), left in the water after treatment. This was, however, unnecessary. The limestone was after a time removed from the tank.	At 5.15 p.m. treatment was commenced. 25 gallons of sodium hypochlorite solution were siphoned slowly into the reservoir from a boat. The boat was dragged rapidly all over the reservoir by means of a long rope pulled by men who ran round and round the sides of the reservoir, while a skilful man in the boat steered its course in such a way as to ensure fair distribution of the germicide. Crosscliffe holds, when *full*, about 1,600,000 gallons.* This would give a proportion of 1 part of sodium hypochlorite to 64,000 parts of water, but in reality the proportion of germicide was higher (about 1 to 45,000).		*Although Crosscliffe and Westgate reservoir hold, when *full*, about 1,600,000 and 700,000 gallons, respectively, it is estimated that together they furnish only about one-twelfth of the day's supply—say, 150,000 gallons per 24 hours. †The fresh sodium hypochlorite solution (rather more than 10 per cent. of "available" chlorine) yields with the dilutions stated the following results :— 1 to 100,000 strong blue. 1 to 1,000,000 faint blue. 1 to 10,000,000 no blue. (*K I* and starch without acid). The various consignments of sodium hypochlorite yielded very constant results as regards available chlorine—usually about 12 per cent. The sodium hypochlorite solution is sold by the United Alkali Company under the trade name of "Chloros."
February 12th -	1 part of sodium hypochlorite to 10,000 parts of rain water as above.		At 5.20 p.m. treatment was commenced. 7 gallons of sodium hypochlorite solution were distributed in the manner explained in the previous column. Westgate holds, when *full*, about 700,000 gallons. This would give a proportion of 1 part of sodium hypochlorite to 100,000 parts of water, but in reality the proportion of germicide was somewhat higher.	
February 13th - -	Treatment continued as above (1 to 10,000). Accumulation of unworked sand on works treated with sodium hypochlorite (1 to 10,000).	5 gallons sodium hypochlorite solution added to contents of reservoir.		

February 14th	By appropriate dilution dose reduced to 1 part of sodium hypochlorite solution to 50,000 parts of raw water. Accumulation of unworked sand on works again treated with sodium hypochlorite (1 to 10,000).		5 gallons sodium hypochlorite solution added to contents of reservoir.
February 15th	Treatment continued as above (1 to 50,000). Accumulation of unwashed sand on " works " again treated with sodium hypochlorite (1 to 10,000).		
February 16th	Treatment continued as above (1 to 50,000).		
February 17th	Treatment continued as above (1 to 50,000).		5 gallons sodium hypochlorite solution added to contents of reservoir.
February 18th	At 7 a.m. dose increased to 1 to 20,000. *Sectional*‡ treatment of the beds commenced at 8.15 p.m. Sodium hypochlorite solution was run in slowly at the inlet angle of filter bed No. 5 by means of an additional apparatus. The outlet water was tested with potassium iodide and starch at short intervals. This concentrated form of treatment was continued until the outlet water gave a decidedly positive blue reaction, when the outlet valve was shut off. This did not occur until the early morning of February 19th, and until 50 gallons of sodium hypochlorite had been added.	10 gallons sodium hypochlorite solution added to contents of reservoir.	
February 19th	The dose remained at 1 to 20,000. As previously explained, bed No. 5 had been heavily dosed in addition, and during the early morning hours the valve was occasionally opened and then shut off again when the iodide starch reaction became unduly pronounced. The object was to permeate the whole bed with the germicidal agent, and this principle of treating the beds separately with large amounts of sodium hypochlorite was persevered with during the ensuing days. At 4 a.m. bed No. 4 was treated in a similar manner, except that for each 10 gallons of sodium hypochlorite solution added the apparatus was shifted to a different angle of the bed. By about 8 a.m. 40 gallons of germicidal solution had been added, and by 10 a.m. the filtered water gave a decided reaction with potassium iodide and starch solutions. The outlet was then shut. After a few hours' rest the valve was occasionally opened and then shut off again when the iodide starch reaction became unduly pronounced as in the case of bed No. 5. At 7.30 p.m. the treatment of bed No. 3 was commenced and carried out on the same lines as in the case of bed No. 5. By midnight, and after the addition of 30 gallons of sodium hypochlorite, the filtered water gave a decidedly positive result with potassium iodide and starch. The valve was closed, and after a sufficient rest gradually opened as before.		5 gallons sodium hypochlorite solution added to contents of reservoir.
February 20th	The dose remained at 1 to 20,000 up to 11.45 p.m., when it was reduced to 1 to 40,000. Between 12 midnight (February 19th) and 1 a.m. (February 20th) the treatment of bed No. 1 was commenced. 20 gallons of sodium hypochlorite were added, and then the outlet valve was closed, as the filtered water gave a decided reaction with potassium iodide and starch. After a suitable rest the valve was gradually opened as in previous experiments. At 7 p.m. the treatment of bed No. 2 was commenced and carried out on similar lines to the above. By 11 p.m., and after the addition of 30 gallons of sodium hypochlorite, the filtered water gave a positive result with the starch iodide test. The outlet valve was closed, and after two hours' rest very gradually opened.	10 gallons sodium hypochlorite solution added to contents of reservoir.	
February 21st	The dose remained at 1 to 40,000. At 6.30 p.m. the treatment of bed No. 6 was commenced. 40 gallons of sodium hypochlorite were used. The procedure was practically the same as in the previous experiments.		
February 22nd	The dose was reduced to 1 to 50,000 at 4 a.m.		
February 23rd	The dose remained at 1 to 10,000. On this day the water in the ballast pit was getting so low that it became necessary to use the Hartsholme water instead.		

‡ Throughout the whole course of the sectional treatment the water passing into consumption was tested with *K.I.* and starch at frequent intervals. The result was either negative or the blue colour so faint as to be represented by the addition of about 1 part of the sodium hypochlorite solution to about 1,000,000 parts of water.

APPENDIX A—*continued.*

DAILY DIARY OF THE "TREATMENT" OF LINCOLN WATER WITH CHLOROS (SODIUM HYPOCHLORITE).

Date.	Treatment of the Raw Water at the Works.	Treatment of Crosscliffe Reservoir Water.	Treatment of Westgate Reservoir Water.	Additional Notes.
February 24th	The dose remained at 1 to 50,000. But, unfortunately, an accident happened to one of the valves of the Worthington engine, from a small piece of limestone being sucked in, which resulted in about 140,000 gallons of untreated water being inadvertently allowed to pass on to the filter beds. As soon as we were informed of the accident we took immediate steps to remedy any possible ill effects. Most of the 140,000 gallons, we were given to understand, would pass on to beds 2 and 3, so we ran 5 gallons of sodium hypochlorite on to each of these beds and distributed it over the surface by means of the currents set up by the inflowing treated water (1 to 50,000), and by inducing waves with the aid of a long pole with a wire gauge scoop at its extremity, which was worked round and round the beds. As regards the other beds, the water lying over the sand gave a decided blue colour with potassium iodide and starch, with the exception of bed No. 1, and this bed had been treating Hartsholme water. Without entering into further detail, we may say that we believe that this accident could not be considered reasonably to have materially affected the successful progress of our treatment.			
February 25th	The dose remained at 1 to 50,000. Instructions were given not to use any of the accumulated unworked sand on the works without first treating it with 10 gallons of sodium hypochlorite suitably diluted with water. This amount we considered sufficient in relation to the bulk of sand.	10 gallons of sodium hypochlorite solution added to contents of reservoir.		
February 26th	The dose remained at 1 to 50,000.		5 gallons of sodium hypochlorite solution added to contents of reservoir.	
February 27th	The dose remained the same except for 4 hours, when, owing to discoloration due to storm water, it was increased to 1 to 20,000. Ditch at Bracebridge treated with $2\frac{1}{2}$ gallons of sodium hypochlorite.			
February 28th	The dose remained at 1 to 50,000 during 16 hours of the 24 hours. Between 6 p.m. and 2 a.m. increased to 1 to 10,000.			
March 1st	The dose remained as on February 28th.		5 gallons of sodium hypochlorite solution added to contents of reservoir.	
March 2nd	The dose remained as on February 28th.			
March 3rd	The dose remained as on February 28th.			
March 4th	The dose remained as on February 28th.	10 gallons of sodium hypochlorite solution added to contents of reservoir, 6.30 p.m.		
March 5th	The dose remained as on February 28th.		5 gallons of sodium hypochlorite solution added to contents of reservoir, 5.50 p.m.	

March 6th	The dose remained as on February 28th.			
March 7th	The dose remained as on February 28th.			
March 8th	The dose remained as on February 28th.		5 gallons of sodium hypochlorite solution added to contents of reservoir, 7.10 p.m.	
March 9th	The dose remained as on February 28th. Treatment of beds, which received chiefly Hartsholme water, commenced at 4.30 p.m. The amount of water coming on to the bed, we were informed, was, roughly speaking, 300,000 gallons a day (24 hours), and the bed was treated with 5 gallons of sodium hypochlorite solution mixed with 5 gallons of water, the rate of flow of the germicide being adjusted so as to deliver the 10 gallons of liquid in 24 hours, thus giving a dose of 1 to 60,000.			
March 10th	Treatment of raw water from pumps and Hartsholme water the same as on March 9th.			
March 11th	Treatment of raw water from pumps and Hartsholme water the same as on March 9th.	5 gallons of sodium hypochlorite solution* added to contents of reservoir, 6.20 p.m.		* This reduced dosage to Crosscliffe reservoir was primarily due to the fact that another boat had been acquired in place of the one before, and it proved quite unsuitable and risky, as the night was very rough.
March 12th	Treatment of raw water from pumps and Hartsholme water the same as on March 9th. The Worthington pumping engine was stopped at midnight for the purpose of cleaning the boilers.		5 gallons of sodium hypochlorite solution added to contents of reservoir, 6.30 p.m.	
March 13th	The Cornish engine was started at 12.10 a.m. We were informed that it pumped on the average 46,000 gallons per hour of raw water. As the water was somewhat turbid, this was treated with 3 gallons of sodium hypochlorite solution per hour, giving a dose of 1 to 15,333, up till 8 a.m., when the dosage was reduced to 1 in 23,000. The rotary pump was started at 6 a.m. This engine, we were informed, pumped 22,000 gallons per hour, and the water was treated with 1 gallon of sodium hypochlorite solution per hour, giving an average dose (after 8 a.m.) of 1 in 22,666 to the mixed waters. For the 24 hours from 4.30 p.m. the dose to the Hartsholme water in bed 1 was reduced to 3 gallons in 24 hours of sodium hypochlorite solution, or approximately 1 in 100,000. This was in consequence of the filtered water from the well in bed 1 giving a decided blue colour with starch and potassium iodide.			
March 14th	The dosage of 1 to 22,666 was continued to the water from the Cornish and rotary pumps. The dosage of bed 1 was again increased to its former amount, viz., 5 gallons in 24 hours.			
March 15th	The treatment was the same as on March 14th.		5 gallons of sodium hypochlorite was added to contents of reservoir.	
March 16th	The treatment was the same as March 15th, except that the rotary pump was stopped for 4 hours, 1 p.m. to 5 p.m., for the purpose of cleaning out one of the filtered water tanks.			
March 17th	The treatment was the same as on March 15th.			
March 18th	The Cornish and rotary engines were stopped at 10.10 a.m., and the Worthington started at 10.25 a.m., and treated with 1 part of sodium hypochlorite solution to 50,000 of water. This dose was continued throughout the night.	5 gallons of sodium hypochlorite solution added to contents of reservoir.		

APPENDIX A—*continued.*

DAILY DIARY OF THE "TREATMENT" OF LINCOLN WATER WITH CHLOROS (SODIUM HYPOCHLORITE).

Date.	Treatment of the Raw Water at the Works.	Treatment of Crosscliffe Reservoir Water.	Treatment of Westgate Reservoir Water.	Additional Notes.
March 19th - -	Treatment of 1 to 50,000 continued. Treatment of Hartsholme water in bed 1 same as above.		5 gallons of sodium hypochlorite solution added to contents of reservoir.	
March 20th - -	Treatment same as March 19th. In consequence of a comparatively strong colour being produced on testing the water in the well in bed 1, it was decided to stop it working. The inlet was closed at 2.45 p.m. and the sterilizer stopped. The water from Hartsholme was almost stopped, but a little perhaps went into bed 4 mixed with the treated water from the pump. It was subsequently discovered that the water in bed 1 was leaking down below the sand behind the plaster on the walls. This was removed during the week and the brickwork "pointed."			
March 21st - -	Treatment of 1 to 50,000 continued to water from the Worthington pump.			
March 22nd - -	Treatment of 1 to 50,000 continued to water from the Worthington pump.			
March 23rd - -	Treatment of 1 to 50,000 continued to water from the Worthington pump.			
March 24th - -	Treatment of 1 to 50,000 continued to water from the Worthington pump.			
	The treatment of the Hartsholme water in No. 1 bed was again commenced, as the bed was repaired and being filled. The sodium hypochlorite solution was run in at the same rate as usual, and when the bed was full, as the outlet was closed, the apparatus was stopped.			
March 25th - -	Same treatment to water from Worthington pump as on March 24th.	5 gallons of sodium hypochlorite solution added to contents of reservoir.		
	The outlet to bed 1 was opened at 12.45, and 5 gallons of sodium hypochlorite mixed with an equal quantity of water allowed to run in at such a rate that the 10 gallons of diluted hypochlorite would be used in 24 hours.			
March 26th - -	Same treatment as on March 25th.		5 gallons of sodium hypochlorite solution added to contents of reservoir.	
March 27th - -	Same treatment as on March 25th.			
March 28th - -	Same treatment as on March 25th.			
March 29th - -	Same treatment as on March 25th.			
March 30th - -	Same treatment as on March 25th.			
March 31st - -	Same treatment as on March 25th.			

April 1st	Same treatment as on March 25th.	5 gallons of sodium hypochlorite solution added to contents of reservoir. The volume of water in the reservoir was about 580,000 gallons.		
April 2nd	Same treatment as on March 25th. The Worthington engine was stopped for 2 hours in the night, and the sterilizer stopped for the same period. The sterilizer to bed 1 was not stopped, although little or no water was coming on to the bed.*		5 gallons of sodium hypochlorite solution was added to contents of thereservoir.	* The reason for this inconsistency was a misunderstanding with the men on duty with the sterilizing apparatus. When the engine stops pumping the filtered water tank becomes full, and very little water will come on the bed. But to avoid any chance of any escaping treatment, we decided to keep the flow of sodium hypochlorite solution running all the time.
April 3rd	The same treatment to the water from the Worthington engine was given as on April 2nd. The engine was stopped for 2 hours as on April 2nd, and the sterilizer to bed 1 was also stopped,† but the full quantity (10 gallons) of diluted sodium hypochlorite solution was added to the contents of bed in the 24 hours.			
April 4th	The same treatment was given to the water from the Worthington pump, which was again stopped for 2 hours in the night. The sterilizer for bed 1 was *not* stopped.† The rotatory engine was used in conjunction with the Worthington, from 10 a.m. to 11 a.m., and from 3.30 p.m. to 4.45 p.m., and the water from it treated with 1 part sodium hypochlorite solution to 44,000 of raw water.			† The reservoir was emptied and cleaned out. The floors and bottom were swilled with water containing about 2 parts of sodium hypochlorite solution in 1,000 of water. Altogether, about 6 gallons of sodium hypochlorite solution were used.
April 5th	The treatment was the same as on April 1st (1 to 50,000).	2½ gallons of sodium hypochlorite solution added to contents of reservoir. Volume of water in the reservoir about 300,000 gallons.	5 gallons of sodium hypochlorite solution added to contents of reservoir.	
April 6th	The treatment was the same as on April 1st (1 to 50,000).			
April 7th	The treatment was the same as on April 1st (1 to 50,000).			
April 8th	The treatment was the same as on April 1st (1 to 50,000).	5½ gallons of sodium hypochlorite solution added to contents of reservoir.		
April 9th	The engine was stopped for 6 hours, from midnight, April 8th, to 6 a.m., and consequently the sterilizer was stopped also. The inlets into beds 1 and 4 were closed during the same period, also a cock connecting the general supply of water to the culvert from Hartsholme and the ballast pits. This prevented any Hartsholme water coming on to any of the beds, and the sterilizer to bed 1, which only contained 1½ gallons half and half mixture, was also stopped.		2½ gallons of sodium hypochlorite solution was added to the contents of the reservoir. Reservoir contained about 300,000 gallons.	
April 10th	The engine again stopped, from 1.20 a.m. to 6 a.m. The same arrangements as to treatment being observed as on April 9th.			
April 11th	The dose remained at 1 in 50,000.			

APPENDIX A—*continued.*

DAILY DIARY OF THE "TREATMENT" OF LINCOLN WATER WITH CHLOROS (SODIUM HYPOCHLORITE).

Date.	Treatment of the Raw Water at the Works.	Treatment of Crosscliffe Reservoir Water.	Treatment of Westgate Reservoir Water.	Additional Notes.
April 12th - - -	At 1 p.m. the dose was reduced to 1 in 100,000 by diluting the sodium hypochlorite to 10 times its original strength and running it in at the rate of 7·5 gallons of the diluted liquid per hour. (*See* February 11th.) The dose to the Hartsholme water was also reduced to one half, by mixing 2·5 gallons of sodium hypochlorite solution with 7·5 gallons water and running the 10 gallons of solution into the bed in 24 hours.		2·5 gallons of sodium hypochlorite solution added to contents of reservoir.	
April 13th - - -	Dose continued at 1 in 100,000. Bed 1 treated with 2½ gallons of sodium hypochlorite solution in 24 hours as on April 12th.			
April 14th - - -	Dose continued at 1 in 100,000. Bed 1 treated with 2½ gallons of sodium hypochlorite solution in 24 hours as on April 12th. Rotatory pumps started at 2 p.m. and run for 3 hours. During this time the water from it was treated with 2·5 gallons of a solution of sodium hypochlorite of 10 per cent. full strength in 1 hour, which is equivalent to 1 in 88,000. Treatment of bed 1 continued as on April 13th.			
April 15th - - -	Treatment of 1 in 100,000 continued. Dose to Hartsholme water in bed 1 same as on April 13th.	5 gallons of sodium hypochlorite solution were added to the contents of the reservoir, 1.10 p.m.		
April 16th - - -	Treatment of 1 in 100,000 continued. Dose to Hartsholme water in bed 1 same as on April 13th.			
April 17th - - -	Treatment of 1 in 100,000 continued. At 5 p.m. bed 1 was shut off for cleaning purposes. The cocks in the raw water mains were so adjusted that No. 4 bed received chiefly Hartsholme water. The sterilizing apparatus was moved over to this bed.		The reservoir was emptied and cleaned out. 5 gallons of sodium hypochlorite solution diluted 350 times with water were used for swilling down the gravel on the "vatters." When only 3 or 4 inches of water (corresponding to about 20,000 gallons) were left in the reservoir, 20 gallons of sodium hypochlorite solution were added and the water well brushed about. This water was, of course, subsequently sent down the drain. After all the dirt had been removed, about ½ gallon of sodium hypochlorite, diluted 350 times, was swilled over the bottom of the reservoir and brushed into the drain.	

April 18th	Dose of 1 in 100,000 continued. Hartsholme water treated in bed 4 except between 11 a.m. and 1.10 p.m., when bed 1 was filling, during which time the sterilizer was moved back to bed 1.		1·5 gallons of sodium hypochlorite solution were added to contents of reservoir at 8 p.m. Reservoir contained about 220,000 gallons.	
April 19th	Dose of 1 in 100,000 continued. 11 a.m. bed 1 started working and sterilizer moved over to that bed. Bed 4 again received chiefly water from Worthington engine.			
April 20th	Dose of 1 in 100,000 continued. Hartsholme water treated in bed 1 as on April 19th.			
April 21st	Treatment as on April 20th.			
April 22nd	Treatment as on April 20th.			
April 23rd	Treatment as on April 20th.			
April 24th	Treatment as on April 20th.			
April 25th	Treatment as on April 20th.			
April 26th	Treatment of 1 in 100,000 continued. An opening was made near the end into the roof of the culvert conveying the water from Hartsholme. At 12.45 sterilizer to bed 1 was transferred to this place, and the same treatment continued.		2·5 gallons of sodium hypochlorite solution were added to contents of reservoir at 7.10 p.m.	
April 27th	Treatment as on April 26th.			
April 28th	Treatment as on April 26th.			
April 29th	Treatment as on April 26th.	2·5 gallons of sodium hypochlorite solution were added to contents of reservoir between 6.5 p.m. and 7.40 p.m. [*See* note*.]		* The method of treating the reservoirs was modified so as to ensure more complete distribution of the sodium hypochlorite. The germicide was siphoned into a vessel containing water which was simultaneously being siphoned into the reservoir. Water was added to the sodium hypochlorite solution in the first vessel so as to keep the level constant for 1 hour. The contents of both vessels were then allowed to drain into the reservoir.
April 30th	Treatment as on April 26th.			
May 1st	Treatment as on April 26th. [Worthington engine stopped for 3 hours (midnight to 3 a.m.) for repairs.]			
May 2nd	Treatment as on April 26th.			
May 3rd	Treatment as on April 26th.		1.30 p.m. to 9.30 p.m., 2·5 gallons of sodium hypochlorite solution were added to the contents of the reservoir in a manner described in footnote, April 29th.	
May 4th	Treatment as on April 26th.			

APPENDIX A—*continued.*

DAILY DIARY OF THE "TREATMENT" OF LINCOLN WATER WITH CHLOROS (SODIUM HYPOCHLORITE).

Date.	Treatment of the Raw Water at the Works.	Treatment of Crosscliffe Reservoir Water.	Treatment of Westgate Reservoir Water.	Additional Notes.
May 5th - - -	Treatment as on April 26th.			
May 6th - - -	Treatment as on April 26th. [Volume of water coming down the Hartsholme tunnel gauged at 214,000 gallons in 24 hours.]			
May 7th - - -	Treatment as on April 26th.		6 p.m. to 8.20 p.m., 2·5 gallons of sodium hypochlorite solution were added to contents of reservoir.	
May 8th - - -	Treatment as on April 26th.			
May 9th - - -	Treatment as on April 26th.			
May 10th - - -	Treatment as on April 26th.		7 p.m. to 8.50 p.m., 2·5 gallons of sodium hypochlorite solution were added to contents of reservoir.	
May 11th - - -	Treatment as on April 26th.			
May 12th - - -	Treatment as on April 26th.			
May 13th - - -	Treatment as on April 26th.			
May 14th - - -	Treatment as on April 26th.		2·5 gallons of sodium hypochlorite solution were added to contents of reservoir.	
May 15th - - -	The Worthington engine was stopped at 12.30 a.m., and the Cornish pump started 1 p.m. The water from this pump was treated with a dose of 1 in 92,000. The rotatory engine was run for a few minutes at 6 a.m., and again for half an hour in the afternoon, the treatment being 1 to 88,000. Treatment of Hartsholme water as on May 14th.			
May 16th - - -	Cornish engine and rotatory engine both working. Treatment as on May 15th. "Condensed"* water run into No. 6 bed, from 7 a.m. to 7.30 a.m., and from 10.30 a.m. until 9.30 a.m. on the following morning. This was treated with 1·8 gallons of sodium hypochlorite which, after suitable dilution, was allowed to mix with the water at the condensed water inlet by running at a uniform rate during the time between 11.30 a.m. and 9.30 a.m. on May 17th. Treatment of Hartsholme water as on May 15th.			* This condensed water consists of the raw water through which the exhaust steam is blown, raising it to a temperature of about 35° C. The amount of treatment was purely arbitrary, as no idea could be obtained as to the quantity of water coming on to the bed from this source.

May 17th	Both Cornish and rotatory engines were working. The treatment of the water from the former was as on May 16th. The water from the latter was, however, not allowed to go on the beds between the hours of 6 a.m. and 4.30 p.m., but was run back into the well from whence it came. The treatment of it was therefore discontinued during that period, but was begun again at 4.30 p.m., when the water was allowed to go on the beds. The treatment was the same as on May 16th. More water from Hartsholme had been turned on consequently for 7 hours, from 4.30 p.m. to 11.30 p.m. The dose to this water was doubled.		2·5 gallons of sodium hypochlorite were added to contents of reservoir.
May 18th	Cornish engine and rotatory engine working treatment as on May 16th.		
May 19th	Cornish engine and rotatory engine working treatment as on May 16th.		
May 20th	The Cornish and rotatory engines were stopped at 7 a.m., and the Worthington engine started. The treatment of the water from this engine was 1 to 100,000, as on May 14th. Treatment of Hartsholme water as on May 19th.	2·5 gallons of sodium hypochlorite were added to contents of reservoir.	
May 21st	Treatment as on May 20th.		2·5 gallons of sodium hypochlorite were added to contents of reservoir.
May 22nd	Treatment as on May 20th. A large number of fresh-water shrimps had appeared in the well of No. 2 bed on May 18th, and the bed had been lying idle while attempts were made to remove these mechanically. As these attempts were not very successful, 1 gallon 5 pints of sodium hypochlorite solution were added to the contents of the well—a dose which was calculated to give 1 part sodium hypochlorite solution to 100 parts water. After standing for 4 hours the water was pumped out from the bottom of the well until it gave only a weak colour with starch and potassic iodide solution. It was then allowed to run slowly into the general mass of filtered water, which was periodically tested, but never gave any trace of colour. This process successfully exterminated the shrimps.		
May 23rd	Treatment of 1 to 100,000 as before.		
May 24th	Treatment of 1 to 100,000 as before.		2·5 gallons of sodium hypochlorite solution were added to contents of reservoir.
May 25th	Treatment of 1 to 100,000 as before.		
May 26th	Treatment of 1 to 100,000 as before. 2·4 ounces (suitably diluted) of sodium hypochlorite solution were run into the well of No. 3 bed (1 in 10,000), the outlet from the bed being closed.		
May 27th	Treatment as on May 25th. The water from Hartsholme was turned off, and the water from the ballast pits turned on at 6.30 p.m. The treatment was continued, however, to the water in the culvert.	4 gallons of sodium hypochlorite solution were added to contents of reservoir.	
May 28th	Treatment as on May 27th.		5 gallons of sodium hypochlorite solution were added to contents of reservoir.

APPENDIX A—*continued*.

DAILY DIARY OF THE "TREATMENT" OF LINCOLN WATER WITH CHLOROS (SODIUM HYPOCHLORITE).

Date.	Treatment of the Raw Water at the Works.	Treatment of Crosscliffe Reservoir Water.	Treatment of Westgate Reservoir Water.	Additional Notes.
May 29th - - -	Treatment of water from Worthington engine on May 28th. Treatment of water in culvert from Hartsholme and ballast pits discontinued at 12.45 p.m.			
May 30th - - -	Dose remained at 1 to 100,000. Increased to 1 to 10,000 for 4 hours from 9.30 p.m. to 1.30 a.m., May 31st.			
May 31st - - -	Dose continued at 1 to 100,000 until 6 p.m. Then increased to 1 to 50,000.		5 gallons of sodium hypochlorite solution were added to contents of reservoir.	
June 1st - - -	The dose remained at 1 to 50,000. As fresh-water shrimps had appeared in the well of No. 3 bed, the outlet was closed and the well treated with $1\frac{3}{8}$ gallons of sodium hypochlorite solution at 4.15 p.m. in a similar manner to the treatment of the well of No. 2 bed on May 22nd. Pumping from the bottom of the well was commenced and continued until 6 a.m. on June 2nd.	5 gallons of sodium hypochlorite solution were added to contents of reservoir.		
June 2nd - - -	The dose remained the same as on June 1st. Several living shrimps were noticeable in the well of No. 3 bed at 6 a.m., so pumping was discontinued and the bed allowed to remain idle. At 6.30 pm. $1\frac{1}{2}$ gallons of sodium hypochlorite were added to the well from a watering-can.			
June 3rd - - -	Treatment the same as on June 2nd. The engine was stopped at 12.30 a.m. and the cocks of the beds so adjusted as to allow the water in No. 3 bed run to waste until a sample pumped from the bottom of the well gave very little colour with starch solution and potassium iodide. The engine was restarted at 2 a.m. The outlet to the bed was closed and the inlet opened. The bed was set to work slowly at 6 a.m., the rate of working being gradually increased during the day. 6 p.m. outlet to No. 6 bed closed. Well treated with a solution of sodium hypochlorite in the proportion of 1 to 100.	6.40 p.m. 7·5 gallons of sodium hypochlorite solution were added to contents of reservoir. Reservoir contained 521,000 gallons.		
June 4th - - -	The dose remained at 1 to 50,000. During the early hours of the morning (12.30 a.m. to 5.30) the outlet cock of No. 6 bed was gradually opened and the contents of the bed allowed to mix with the rest of the filtered water.		7·5 gallons of sodium hypochlorite solution were added to contents of reservoir.	
June 5th - - -	The dose remained at 1 to 50,000. The well of No. 4 bed treated with sodium hypochlorite solution in the proportion of 1 to 100 at 4 p.m., the outlet from the bed having been closed.			
June 6th - - -	The dose remained at 1 to 50,000 except for four hours (8 p.m. to 12 p.m.), when it was increased to 1 to 10,000. The outlet of No. 4 bed gradually opened between midnight, June 5th, and 6 a.m .to allow the contents to slowly mix with the rest of the filtered water.	7·5 gallons of sodium hypochlorite solution were added to contents of reservoir, which contained 477,000 gallons of water.		

June 7th	The dose remained at 1 to 50,000. Engine stopped from 3 a.m. to 5 a.m. for the purpose of removing weeds from the pike drain.		8 gallons of sodium hypochlorite solution were added to contents of reservoir, which contained 573,000 gallons of water.	
June 8th	The dose remained at 1 to 50,000. The false bottom of the new bed (No. 7) having been covered with water siphoned out of No. 6 bed, this water was treated with 23 gallons of sodium hypochlorite solution, which is calculated to be in the proportion of 1 to 1,000 of water.			
June 9th	The dose remained at 1 to 50,000.			
June 10th	The dose remained at 1 to 50,000.	3·5 gallons of sodium hypochlorite solution were added to 243,000 gallons of water in reservoir.		
June 11th	The dose remained at 1 to 50,000. No. 1 bed filled up from below with filtered water, 12 midnight, June 10th, to 1.15 a.m., during which time the engine was stopped. Part of the water in No. 7 bed was pumped out.		7·5 gallons of sodium hypochlorite solution were added to the 597,000 gallons of water in reservoir.	
June 12th	Dose remained at 1 to 50,000.			
June 13th	Dose remained at 1 to 50,000.	8·5 gallons of sodium hypochlorite solution were added to contents of reservoir.		
June 14th	Dose remained at 1 to 50,000. No. 1 bed started to work slowly.		7·5 gallons of sodium hypochlorite solution were added to contents of reservoir.*	* From this date onwards the germicide was added to contents of reservoir in a different way. The sodium hypochlorite solution was poured into a watering-can fitted with a rose, and was diluted with water to such a degree as would ensure the whole amount of solution being added within reasonable time. The contents of the can were then run into the reservoir by a man standing in the boat and waving the can about.
June 15th	Dose remained at 1 to 50,000.			
June 16th	Dose remained at 1 to 50,000. As No. 5 bed was found to leak very considerably, it was shut off for repairs and the water allowed to leak away.			
June 17th	The dose remained at 1 to 50,000.	10 gallons of sodium hypochlorite solution were added to contents of reservoir.		
June 18th	The dose remained at 1 to 50,000.		12·5 gallons of sodium hypochlorite solution were added to contents of reservoir.	The boat was rowed about as before. This ensured a much better distribution of the sodium hypochlorite solution.
June 19th	The dose remained at 1 to 50,000.			
June 20th	The dose remained at 1 to 50,000. In order to kill a number of fresh-water fleas in No. 6 bed (filtered water) ·85 gallon of sodium hypochlorite solution was run down the well and air pipes of the bed, during the morning, the bed being, of course, shut off.	10 gallons of sodium hypochlorite solution were added to contents of reservoir.		

APPENDIX A—*continued.*

DAILY DIARY OF THE "TREATMENT" OF LINCOLN WATER WITH CHLOROS (SODIUM HYPOCHLORITE).

Date.	Treatment of the Raw Water at the Works.	Treatment of Crosscliffe Reservoir Water.	Treatment of Westgate Reservoir Water.	Additional Notes.
June 21st - - -	The dose remained at 1 to 50,000. The outlet of No. 6 bed was opened at 12.5 a.m and the contents of the bed gradually allowed to mix with the rest of the filtered water during the early hours of the morning.		13 gallons of sodium hypochlorite solution were added to contents of reservoir.	
June 22nd - -	The dose remained at 1 to 50,000 with the exception of 4 hours, from 8 p.m. to midnight, when it was increased to 1 to 10,000.			
June 23rd - - -	Dose remained at 1 to 50,000. Engine stopped, midnight, June 22nd, to 2.20 a.m., for the purpose of running off No. 2 bed. A new well having been put into No. 2 bed, 3·5 gallons of sodium hypochlorite solution were added to the contents of the bed.			
June 24th - - -	Dose 1 to 50,000 until 8 p.m.; 8 p.m. to 12 p.m. 1 to 10,000. Engine stopped, midnight, June 23rd, until 2.45 a.m., and the rest of the water in No. 2 bed run to waste. The bed was then partially filled up from below with filtered water.	10 gallons of sodium hypochlorite solution were added to the contents of the reservoir.		
June 25th - - -	Dose 1 to 50,000.		15 gallons of sodium hypochlorite solution were added to contents of reservoir.	
June 26th - - -	Dose, midnight, June 25th, to 8 p.m., 1 to 50,000; 8 p.m. to midnight, 1 to 10,000.	15 gallons of sodium hypochlorite solution were added to contents of reservoir.		
June 27th - - -	Dose the same as on June 26th.		30 gallons of sodium hypochlorite solution were added to contents of reservoir.	
June 28th - - -	Dose the same as on June 26th.	10 gallons of sodium hypochlorite solution were distributed over whole of reservoir, and 15 gallons more over the half of reservoir farther from inlet to outlet pipe. Contents of reservoir, 423,000 gallons.		

June 29th	Dose the same as on June 26th. Engine stopped for an hour (12.15 p.m. to 1.15 a.m.) to examine the " new " clear water tank. A large crack was found in the wall at the far end, and a leak in the floor in the corner formed by the south wall of the tank and the west wall of the raw water well of the Cornish engine.		
June 30th	The dose remained the same as on June 29th.		
July 1st	The dose remained the same as on June 29th.	30 gallons of sodium hypochlorite solution were distributed over the half of reservoir farthest from inlet. Contents of reservoir, 583,000 gallons.	
July 2nd	The dose remained the same as on June 29th. The leaks in the clear water tank were repaired, 12.30 p.m. to 7.30 a.m. As only one tank could be used, the engine had to be worked half speed, and the rate of flow of the sodium hypochlorite solution into the raw water tank was proportionately reduced during this time. After the repairs were completed, the bottom of the tank was treated with 1 pint of sodium hypochlorite solution, suitably diluted. This was subsequently pumped out.		19 gallons of sodium hypochlorite solution were distributed over the half of reservoir farthest from inlet. Contents of reservoir, 375,000 gallons.
July 3rd	Dose as on July 2nd. Midnight to 8 p.m. 1 to 50,000 ; 8 p.m. to midnight 1 to 10,000.	25 gallons of sodium hypochlorite solution were distributed over the half of reservoir farthest from inlet. Contents of reservoir, 488,000 gallons.	
July 4th	Dose as on July 2nd. Midnight to 8 p.m. 1 to 50,000 ; 8 p.m. to midnight 1 to 10,000.		18·5 gallons of sodium hypochlorite solution were distributed over the half of reservoir farthest from inlet. Contents of reservoir, 368,000 gallons.
July 5th	Dose as on July 2nd. Midnight to 8 p.m. 1 to 50,000 ; 8 p.m. to midnight 1 to 10,000.	22·5 gallons of sodium hypochlorite solution were distributed over the half of reservoir farthest from inlet. Contents of reservoir, 445,000 gallons.	
July 6th	Dose 1 to 50,000 midnight to 2 p.m. ; 2 p.m. increased to 1 to 10,000.		32·5 gallons of sodium hypochlorite solution were distributed over the half of reservoir farthest from inlet. Contents of reservoir, 326,000 gallons.

APPENDIX A—*continued.*

DAILY DIARY OF THE "TREATMENT" OF LINCOLN WATER WITH CHLOROS (SODIUM HYPOCHLORITE).

Date.	Treatment of the Raw Water at the Works.	Treatment of Crosscliffe Reservoir Water.	Treatment of Westgate Reservoir Water.	Additional Notes.
July 7th - - -	Dose remained at 1 to 10,000 during the whole of the 24 hours.			
July 8th - - -	Dose remained at 1 to 10,000 during the whole of the 24 hours.	45 gallons of sodium hypochlorite solution were distributed over the half of reservoir farthest from inlet. Contents of reservoir, 466,000 gallons.		
July 9th - - -	Dose remained at 1 to 10,000.	45 gallons of sodium hypochlorite solution were distributed over the half of reservoir farthest from inlet.	30 gallons of sodium hypochlorite solution were distributed over the half of reservoir farthest from inlet.	
July 10th - - -	Dose remained at 1 to 10,000 until 1 p.m., when it was reduced to 1 to 50,000.	45 gallons of sodium hypochlorite solution were distributed over the half of reservoir farthest from inlet.	30 gallons of sodium hypochlorite solution were distributed over the half of reservoir farthest from inlet.	
July 11th - - -	Dose remained at 1 to 50,000.		30 gallons of sodium hypochlorite solution were distributed over the half of reservoir farthest from inlet.	
July 12th - - -	Dose remained at 1 to 50,000.	45 gallons of sodium hypochlorite solution were distributed over the half of reservoir farthest from inlet.		
July 13th - - -	Dose remained at 1 to 50,000.		30 gallons of sodium hypochlorite solution were distributed over the half of reservoir farthest from inlet.	
July 14th - - -	Dose remained at 1 to 50,000 until 2 p.m., at which time it was increased to 1 to 25,000.	45 gallons of sodium hypochlorite solution were distributed over the half of reservoir farthest from inlet.		

July 15th - - -	Dose remained at 1 to 25,000. Rotatory pumping engine started at 12 o'clock (midnight, July 14th). Dose 1 to 22,000 to the water from this engine.		30 gallons of sodium hypochlorite solution were distributed over the half of reservoir farthest from inlet.	
July 16th - - -	Dose :—Water from Worthington engine 1 to 25,000. Water from rotatory engine 1 to 22,000.	45 gallons of sodium hypochlorite solution were distributed over the half of reservoir farthest from inlet.		
July 17th - - -	Dose until 6 a.m. the same as on July 16th. At 6 a.m. the Worthington engine was stopped and the Cornish engine started. The dose to the water from this engine was 1 to 23,000.			
July 18th - - -	Dose :—Water from Cornish engine 1 to 23,000. Water from rotatory engine 1 to 22,000.			
July 19th - - -	Dose remained the same as on July 18th.			
July 20th - - -	Dose remained the same as on July 18th.			
July 21st - - -	Dose remained the same as on July 18th. The so-called condensed * water was turned into No. 6 bed from 9.30 a.m. to 4 p.m., and was treated with sodium hypochlorite solution at the rate of 1 pint in 10 minutes. As there was no possibility of gauging the amount of this water coming on the bed, this treatment was purely arbitrary, but it sufficed to cause the water in the bed to give the same colour with starch and potassic iodide solution at 4 p.m. as it did before the condensed water was started.			* *See* footnote, May 16th.
July 22nd - - -	The dose remained the same as on July 21st.			
July 23rd - - -	The dose remained as on July 22nd up to 6 p.m. At 6 p.m. the Cornish engine was stopped and the rotatory engine continued working from Nos. 1 and 4 beds, the dose remaining the same. The Worthington was started at 10 p.m. Dose 1 to 25,000. Between 6 p.m. and 10 p.m. the clear water connections were made with No. 7 bed and the limestone was removed from the "new" clear water tank. After all the limestone was removed, the tank was swilled out with 25 gallons of water containing 1·5 pints of sodium hypochlorite solution. Most of this water, however, drained away.			
July 24th - - -	The dose remained at :— Water from Worthington engine, 1 to 25,000. Water from rotatory engine 1 to 22,000, until 6 p.m. At 6 p.m., the dose was reduced to :— Water from Worthington engine, 1 to 100,000. Water from rotatory engine, 1 to 88,000. 11 p.m.—Rotatory engine stopped working.			
July 25th - - -	Dose remained at 1 to 100,000 until 6 a.m. 6 a.m. to 6 p.m. dose 1 to 25,000. 6 p.m. to 6 a.m. (July 26th) dose 1 to 100,000.			

APPENDIX A—*continued.*

DAILY DIARY OF THE "TREATMENT" OF LINCOLN WATER WITH CHLOROS (SODIUM HYPOCHLORITE).

Date.	Treatment of the Raw Water at the Works.	Treatment of Crosscliffe Reservoir Water.	Treatment of Westgate Reservoir Water.	Additional Notes.
July 26th - - -	Dose as on July 25th. Rotatory engine worked from 6 p.m. to 9 p.m. Dose 1 to 88,000.			
July 27th - - -	Dose as on July 25th.			
July 28th - - -	Dose remained at 1 to 100,000 until 2 a.m. At 2 a.m. the water from the pike drain intake was shut off and the rotatory engine started in place of the Worthington. Dose 1 to 88,000. The pike drain was cleaned out. The rotatory engine was stopped and the Worthington engine started at 5 a.m. As a quantity of muddy water was coming on to the beds, the dose was increased to 1 to 10,000 from 5.15 a.m. to 6 a.m., being reduced to 1 to 25,000 at 6 a.m. Rotatory engine re-started at 7.30 a.m. Dose 1 to 25,000. At 6 p.m. dose to water from both engines reduced to 1 to 100,000.			

The following notes (from July 29th onwards) were kindly supplied to us by Mr. N. M. Barron.

1905.	
July 29th - - - -	Chloros 1 in 100,000. Worthington and flywheel working. Flywheel stopped, 6 a.m.
July 30th - - - -	Chloros 1 in 100,000. Worthington working.
July 31st - - - -	Chloros 1 in 100,000. Worthington working.
August 1st, 2nd, 3rd, 4th, 5th 6th, 7th, 8th, 9th, 10th, 11th, 12th, 13th, 14th, 15th, 16th.	Chloros 1 in 100,000. Worthington working.
August 17th - - - -	Chloros increased to 1 in 25,000 from 6 p.m. Commenced temporary pumping from river, 8 a.m. Worthington working.
August 18th, 19th 20th - -	Chloros 1 in 25,000. Temporary pumping from river. Worthington working.
August 21st, 22nd, 23rd, 24th, 25th.	Chloros 1 in 25,000. Worthington working. Temporary pumping from river.
August 26th - - - -	Chloros 1 in 25,000. Temporary pumping at river stopped at noon. Worthington working.
August 27th - - - -	Chloros 1 in 25,000. No pumping from river. Worthington working.
August 28th - - - -	Chloros 1 in 25,000. Pumping from river, 8.30 a.m. to 6 p.m. Worthington working.
August 29th, 30th, 31st and September 1st.	Chloros 1 in 25,000. No pumping at river. Worthington working.
September 2nd - - -	Chloros 1 in 25,000. Worthington working. Flywheel started, 10.30 p.m.
September 3rd - - -	Chloros 1 in 25,000. Worthington working. Flywheel stopped, 10.50 a.m.
September 4th, 5th, 6th, 7th, 8th, 9th.	Chloros 1 in 25,000. Worthington working.
September 10th - - -	Chloros reduced to 1 in 50,000, 6 p.m. Worthington working.
September 11th, 12th, 13th, 14th 15th.	Chloros 1 in 25,000, 6 a.m. to 6 p.m.; 1 in 50,000, 6 p.m. to 6 a.m. Worthington working.
September 16th - - -	Chloros 1 in 25,000, 6 a.m. to 6 p.m.; 1 in 50,000, 6 p.m. to 6 a.m. Worthington stopped, 8.30 p.m. Flywheel started, 8.30 p.m.
September 17th - - -	Chloros 1 in 25,000, 6 a.m. to 6 p.m.; 1 in 50,000, 6 p.m. to 6 a.m. Cornish started 8.30 p.m. All water from river from 8.30 p.m.
September 18th, 19th, 20th, 21st, 22nd.	Chloros 1 in 25,000, 6 a.m. to 6 p.m.; 1 in 50,000, 6 p.m. to 6 a.m. Cornish and flywheel engines working.
September 23rd - - -	Chloros 1 in 25,000, 6 a.m. to 6 p.m.; 1 in 50,000, 6 p.m. to 6 a.m. Worthington started, 11.15 a.m. Cornish and flywheel stopped, 11.15 a.m.
September 24th, 25th, 26th -	Chloros 1 in 25,000, 6 a.m. to 6 p.m.; 1 in 50,000, 6 p.m. to 6 a.m. Worthington working.
September 27th - - -	Chloros 1 in 100,000, from 11 am. Worthington working.
September 28th to October 23rd	Chloros 1 in 100,000. Worthington working.
October 24th - - - -	Chloros 1 in 100,000. Worthington Working. Flywheel working, 10 a.m. to 6 p.m.
October 25th to November 5th	Chloros 1 in 100,000. Worthington working.
November 6th - - -	Chloros 1 in 1,000,000, from 11.15 a.m. Worthington working.
November 7th to 18th - -	Chloros 1 in 1,000,000. Worthington working.
November 19th - - -	Chloros 1 in 1,000,000. Worthington stopped and Cornish started, 8.30 p.m.
November 20th - - -	Chloros increased to 1 in 100,000, at 10 a.m. Cornish working. Flywheel started, 6 a.m.
November 21st to 24th - -	Chloros 1 in 100,000. Cornish and flywheel working.
November 25th - - -	Chloros 1 in 100,000. Stopped Cornish and flywheel engines and started Worthington, 10 a.m.
November 26th - - -	Chloros 1 in 100,000. Stopped Worthington and started Cornish and flywheel, 10 a.m. Stopped flywheel, 7 p.m.
November 27th - - -	Chloros 1 in 100,000 to 11.15 a.m., then reduced to 1 in 1,000,000. Cornish stopped, 12.35 a.m.; restarted, 2.30 a.m. Flywheel started, 3 a.m. Worthington started. 1 a.m.; stopped, 2.30 a.m.
November 28th - - -	Chloros 1 in 1,000,000. Cornish and flywheel stopped, and Worthington started at 10.30 a.m.
November 29th - - -	Chloros 1 in 1,000,000. Worthington working.
November 30th - - -	Chloros 1 in 1,000,000. Worthington working.
December 1st - - -	Chloros 1 in 1,000,000. Worthington working.
December 2nd - - -	Chloros 1 in 1,000,000. Worthington working.
December 3rd - - - -	Chloros 1 in 1,000,000. Worthington working.
December 4th - - - -	Chloros increased to 1 in 100,000 from 6 a.m. Worthington working.
December 5th to 10th - -	Chloros 1 in 100,000. Worthington working.
December 11th - - -	Chloros 1 in 1,000,000 from 6 a.m. to 3.15 p.m.; 1 in 100,000 from 3.15 p.m. Worthington working.
December 12th to 28th - -	Chloros 1 in 100,000. Worthington working
December 29th - - -	Chloros 1 in 100,000 to 2 p.m.; 1 in 1,000,000 from 2 p.m. Worthington working.
December 30th - - -	Chloros 1 in 1,000,000. Worthington working.
December 31st - - -	Chloros 1 in 1,000,000. Worthington working.
1906.	
January 1st - - - -	Chloros 1 in 1,000,000. Worthington working.
January 2nd - - - -	Chloros 1 in 1,000,000 to 10.30 a.m.; 1 in 100,000 from 10.30 a.m. Worthington working.
January 3rd to 6th - - -	Chloros 1 in 100,000. Worthington working.
January 7th - - - -	Chloros 1 in 100,000. Worthington stopped and Cornish started, 9 a.m. Flywheel started, 11 p.m.
January 8th - - - -	Chloros 1 in 100,000. Cornish working, flywheel stopped, 9.30 a.m.; started, 8 p.m.
January 9th - - - -	Chloros 1 in 100,000. Cornish working, flywheel stopped, 11.30 a.m.
January 10th - - -	Chloros increased to 1 in 10,000 at 4.30 p.m. Cornish working, flywheel started, 5.15 p.m.
January 11th - - - -	Chloros 1 in 10,000. Cornish and flywheel working.
January 12th - - - -	Chloros 1 in 10,000. Cornish and flywheel working.
January 13th - - - -	Chloros 1 in 10,000. Cornish working. Flywheel stopped, 6 p.m.
January 14th - - - -	Chloros 1 in 10,000. Cornish working. Flywheel started, 6 a.m.; stopped, 6 p.m.
January 15th - - - -	Chloros 1 in 10,000. Cornish working. Flywheel started, 6 a.m.
January 16th - - - -	Chloros 1 in 10,000. Cornish working. Flywheel stopped, 8 p.m.
January 17th - - - -	Chloros 1 in 10,000. Cornish working. Flywheel started, 4 a.m.

1906.	
January 18th	Chloros 1 in 10,000. Cornish working. Flywheel stopped, 10 p.m.
January 19th	Chloros 1 in 10,000. Cornish working. Flywheel started, 5 a.m.
January 20th	Chloros 1 in 10,000. Worthington started. Cornish and flywheel stopped, 3 p.m.
January 21st to 26th	Chloros 1 in 10,000. Worthington working.
January 27th	Chloros 1 in 10,000. Worthington stopped, 8 p.m. Flywheel started, 1 p.m.
January 28th	Chloros 1 in 10,000. Worthington started, 3.30 a.m. Flywheel stopped, 4 a.m.
January 29th	Chloros reduced to 1 in 20,000 at 5.15 p.m. Worthington working.
January 30th	Chloros 1 in 20,000. Worthington working.
January 31st	Chloros reduced to 1 in 100,000 at 6 p.m. Worthington working.
February 1st to 10th	Chloros 1 in 100,000. Worthington working.
February 11th	Chloros 1 in 100,000. Worthington stopped and Cornish started, 8.30 p.m.
February 12th	Chloros 1 in 100,000. Cornish working. Flywheel started, 5.30 a.m.; stopped, 10 p.m.
February 13 and 14th	Chloros 1 in 100,000. Cornish working. Flywheel started, 6 a.m.; stopped, 10 p.m.
February 15th and 16th	Chloros 1 in 100,000. Cornish working. Flywheel started, 5.30 a.m.; stopped, 10 p.m.
February 17th	Chloros 1 in 100,000. Flywheel started, 5.30 a.m. Cornish and flywheel stopped and Worthington started, 10.30 a.m.
February 18th	Chloros increased to 1 in 10,000 at 11.45 a.m. River thick and muddy; started raking beds, 11.45 a.m. Worthington working.
February 19th	Chloros 1 in 10,000. River thick, no raking. Worthington working.
February 20th	Chloros reduced to 1 in 20,000 at 12 noon. River muddy, no raking, Worthington working.
February 21st	Chloros neat from 5 to 6 a.m.; reduced to 1 in 20,000, 6 a.m.; reduced to 1 in 100,000 at 5.30 p.m.; increased to 1 in 10,000 at 7.45, and reduced to 1 in 100,000 at 9.45 p.m. River muddy, raking beds, 5 to 6 a.m. Worthington stopped. Cornish and flywheel working, 9.30 to 1.30 p.m. Worthington stopped and Cornish and flywheel started, 6 p.m.
February 22nd	Chloros increased to 1 in 50,000 at 4.30 p.m. Cornish and flywheel working. Flywheel stopped, 10.30 p.m.
February 23rd	Chloros 1 in 50,000. Cornish working. Flywheel started, 3.30 a.m.
February 24th	Chloros 1 in 50,000. Worthington started. Flywheel and Cornish stopped, 10 p.m.
February 25th	Chloros 1 in 50,000. Worthington working.
February 26th	Chloros reduced to 1 in 100,000 at 6 a.m. Worthington working.
February 27th	Chloros 1 in 100,000. Worthington working.
February 28th to March 4th	Chloros 1 in 100,000. Worthington working.
March 5th	Chloros increased to 1 in 10,000 at 12.30 p.m.; reduced to 1 in 100,000 at 2.30 p.m. Worthington working.
March 6th to 15th	Chloros 1 in 100,000. Worthington working.
March 16th to 23rd	Chloros 1 in 100,000. Worthington working.
March 24th	Chloros 1 in 100,000. Worthington stopped, 5.15 p.m. Cornish started, 7.45 p.m. Flywheel started, 5.40 p.m.
March 25th	Chloros 1 in 100,000. Cornish working. Flywheel stopped, 5 a.m.
March 26th	Chloros 1 in 100,000. Cornish stopped and Worthington started, 7.50 a.m.
March 27th to April 6th	Chloros 1 in 100,000. Worthington working.
April 7th	Chloros 1 in 100,000. Worthington stopped, 2.10 p.m. Flywheel started at 11 a.m.
April 8th	Chloros 1 in 100,000. Flywheel working.
April 9th	Chloros 1 in 100,000. Flywheel stopped, 1.30 a.m.; restarted, 11 a.m., and stopped, 6 p.m. Worthington started, 12.45 a.m.
April 10th	Chloros 1 in 100,000. Worthington stopped. Cornish and flywheel started, 10.30 a.m.
April 11th	Chloros 1 in 100,000. Cornish and flywheel working.
April 12th	Chloros 1 in 100,000. Cornish and flywheel working.
April 13th	Chloros 1 in 100,000. Cornish working. Flywheel stopped, 10 p.m.
April 14th	Chloros 1 in 100,00. Cornish working. Flywheel started, 5 a.m., stopped, 11 p.m.
April 15th	Chloros increased to 1 in 10,000, 12 noon; reduced to 1 in 100,000, 6 p.m. Worthington, started 12 noon. Flywheel started, 8 a.m., stopped, 12 noon. Cornish stopped, 12 noon. River water shut out and entire supply taken from Hartsholme and ballast pits at 12 noon.
April 16th	Chloros 1 in 100,000, up to 9.50 a.m. stopped altogether. Worthington working.
April 17th	No Chloros. Worthington.
April 18th to May 1st	No Chloros. Worthington working.
May 2nd	Chloros 1 in 100,000, from 9 a.m. Worthington working. Hartsholme and ballast pit water shut off and river water used, 9 a.m.
May 3rd	Chloros 1 in 100,000. Worthington working.
May 4th	Chloros 1 in 100,000. Worthington working.
May 5th to 18th	Chloros 1 in 100,000. Worthington working.
May 19th	Chloros 1 in 100,000. Worthington working. Ballast pit water first used for street drays without chloros, and Willoughby stopped.
May 20th to June 17th	Chloros 1 in 100,000. Worthington working.
June 18th	Chloros 1 in 100,000. Worthington stopped and Cornish and flywheel started, 9.30 a.m.
June 19th to 22nd	Chloros 1 in 100,000. Cornish and flywheel working.
June 23rd	Chloros 1 in 100,000. Worthington started, and Cornish and flywheel stopped, 10.15 a.m.
June 24th to July 16th	Chloros 1 in 100,000. Worthington working.
July 17th	Chloros 1 in 100,000. Worthington stopped. Cornish and flywheel started, 7.30 a.m.
July 18th and 19th	Chloros 1 in 100,000. Cornish and flywheel working.
July 20th	Chloros 1 in 100,000. Worthington started. Cornish and flywheel stopped, 7 a.m.
July 21st and 22nd	Chloros 1 in 100,000. Worthington working.
July 23rd	Chloros 1 in 100,000. Worthington stopped, 10 p.m. Flywheel started, 10.20 p.m.
July 24th	Chloros 1 in 100,000. Worthington started, 3 a.m. Flywheel stopped, 2.50 a.m.
July 25th	Chloros 1 in 100,000. Worthington working. Flywheel started, 7 a.m., stopped, 8 p.m.
July 26th to August 20th	Chloros 1 in 100,000. Worthington working.
August 21st	Chloros 1 in 100,000. Worthington stopped. Cornish and flywheel started, 7 a.m.
August 22nd, 23rd, 24th	Chloros 1 in 100,000. Cornish and flywheel working.
August 25th	Chloros 1 in 100,000. Worthington started. Cornish and flywheel stopped, 9.30 a.m.
August 26th	Chloros 1 in 100,000. Worthington working.
August 27th	Chloros 1 in 100,000. Worthington stopped. Cornish and flywheel started, 11.30 a.m.

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August 28th, 29th, 30th, 31st	Chloros 1 in 100,000. Cornish and flywheel working.
September 1st	Chloros 1 in 100,000. Cornish and flywheel stopped, 12.15 noon.
September 2nd	Chloros 1 in 100,000. Worthington started, 12 midnight.
September 3rd to October 23rd	Chloros 1 in 100,000. Worthington working.
October 24th	Chloros 1 in 100,000. Worthington stopped. Cornish and flywheel stopped, 12.30 noon.
October 25th, 26th, 27th	Chloros 1 in 100,000. Cornish and flywheel working.
October 28th	Chloros 1 in 100,000. Worthington started, 11.45 a.m. Cornish and flywheel stopped.
October 29th, 30th, 31st to November 2nd.	Chloros 1 in 10,000. Worthington working.
November 3rd	Chloros 1 in 100,000 to 6 p.m. then stopped. River water shut out at 3 p.m., and Hartsholme water being used. Worthington working pumped to waste till 5.45 p.m. Last day ballast pit water supplied to street drays.
November 4th and 5th	No chloros. All Hartsholme and ballast pit water used. Worthington working.
November 6th	Chloros 1 in 100,000 in river water only. River water being used along with Hartsholme and ballast pit water 11.30 p.m. to 5 a.m. Worthington working.
November 7th	Chloros nil. Using all Hartsholme and ballast pit water. Worthington working.
November 8th to 13th	Chloros nil. Using all Hartsholme and ballast pit water. Worthington working.
November 14th	Chloros 1 in 100,000. Hartsholme, ballast pit and river water from 12 noon. Worthington working.
November 15th, 16th, 17th	Chloros 1 in 100,000. Hartsholme ballast pit and river water. Worthington working.
November 18th	Chloros 1 in 100,000 to 6 p.m. River water shut out and Hartsholme and ballast pit water used from 6 p.m. Worthington working.
November 19th, 20th, 21st, 22nd.	Chloros nil. Using all Hartsholme and ballast pit water. Worthington working.
November 23rd	Chloros 1 in 100,000 from 1 p.m. River, Hartsholme and ballast pit water being used from 1 p.m. Worthington working.
November 24th	Chloros 1 in 100,000. River, Hartsholme and ballast pit water. Worthington working.
November 25th	Chloros 1 in 100,000. River, Hartsholme and ballast pit water. Worthington stopped, 6 a.m. Cornish and flywheel started, 6 a.m.; stopped 1 p.m., and Worthington started.
November 26th	Chloros 1 in 100,000. River, Hartsholme and ballast pit water. Worthington working.
November 27th to December 3rd.	Chloros 1 in 100,000. River, Hartsholme and ballast pit water. Worthington working.
December 4th	Chloros 1 in 100,000. River, Hartsholme and ballast pit water. Worthington stopped and Cornish and flywheel started, 8 a.m.
December 5th to 16th	Chloros 1 in 100,000. River, Hartsholme and ballast pit water. Cornish and flywheel working.
December 17th	Chloros 1 in 100,000 to 7.15 a.m. River water shut out and no chloros used. Cornish and flywheel working.
December 18th	Chloros nil. Hartsholme and ballast pit water. Cornish and flywheel working.
December 19th	Chloros nil. Hartsholme and ballast pit water. Cornish and flywheel stopped and Worthington started at 1.45 p.m.
December 20th	Chloros nil. Hartsholme and ballast pit water. Worthington working.
December 21st	Chloros 1 in 100,000 from 11 a.m. River water taken in at 11 a.m. together with Hartsholme and ballast pit water. Worthington working.
December 22nd to January 1st	Chloros 1 in 100,000. River, Hartsholme and ballast pit water. Worthington working.
1907.	
January 2nd	Chloros 1 in 100,000 to 3 a.m. River water shut out and Hartsholme and ballast pit water used from 3 a.m. Worthington working.
January 3rd to 14th	Chloros nil. Hartsholme and ballast pit water used. Worthington working.
January 15th	Chloros 1 in 100,000 from 6 a.m. River water taken in together with Hartsholme and ballast pit. Worthington working.
January 16th to February 12th	Chloros 1 in 100,000. River, Hartsholme and ballast pit water. Worthington working.
February 13th	Chloros 1 in 100,000 to 4 a.m. River water shut out 4 a.m. Chloros stopped. Hartsholme and ballast pit water only. Worthington working.
February 14th and 15th	Chloros nil. Hartsholme and ballast pit water being used. Worthington working.
February 16th	Chloros nil. Hartsholme and ballast pit water being used. Worthington stopped. Cornish and flywheel started, 9.30 a.m.
February 17th	Chloros nil. Hartsholme and ballast pit water used. Cornish and flywheel working.
February 18th	Chloros 1 in 100,000 from 9 a.m. River water taken in at 9 a.m. together with Hartsholme and ballast pit. Cornish and flywheel working.
February 19th	Chloros 1 in 100,000 to midnight. River, Hartsholme and ballast pit being used to midnight. River then shut out. Cornish and flywheel working.
February 20th	Chloros 1 in 100,000 from 11 a.m. River water taken in at 11 a.m. with Hartsholme and ballast pit. Cornish and flywheel working.
February 21st to 28th	Chloros 1 in 100,000. River, Hartsholme and ballast pit. Cornish and flywheel working.

The following additional notes referring to various alterations carried out by Mr. Barron at the Pumping Station may here be added :—

September 17th, 1905	Old intakes from catchwater drain and pike drain abandoned and new intake from river brought into use.
December 7th, 1905	Crosscliffe Reservoir abandoned owing to excessive leakage.
April 17th, 1906	New cast iron main from Hartsholme and ballast pit completed, and town supplied entirely from these sources for a time.
May 17th, 1906	Alterations (to effect individual control, etc.) to No. 5 filter bed completed.
June 8th, 1906	Alterations (to effect individual control, etc.) to No. 7 filter bed completed.
June 28th, 1906	Alterations (to effect individual control, etc.) to No. 1 filter bed completed.
July 21st, 1906	Alterations (to effect individual control, etc.) to No. 6 filter bed completed.
August 2nd, 1906	Alterations (to effect individual control, etc.) to No. 3 filter bed completed.
August 17th, 1906	Alterations (to effect individual control, etc.) to No. 2 filter bed completed.
August 31st, 1906	Alterations (to effect individual control, etc.) to No. 4 filter bed completed.
July 13, 1906	New raw water tank completed and all "raw" water delivered to filter beds through an aerating standpipe.
September 2nd, 1906	New clear water tank completed, and total clear water from filters measured by "Venturi" meter.

APPENDIX B.

BACTERIOLOGICAL RESULTS.

TABLE I.

CATCHWATER DRAIN WATER.

NUMBER OF B. COLI (OR COLI-LIKE MICROBES).

Description of the Sample.	Number of B. Coli (or coli-like microbes).				
	+ 100 c.c. of water.	+ 10 c.c. of water.	+ 1 c.c. of water.	+ ·1 c.c. of water.	+ ·01 c.c. of water.
Catchwater Drain Water.					
(14) 1. Collected ½ mile above intake - - 21/2/05	flag (ac) +	flaginac* +	flaginac +	—	
(20) 2. Collected from well at Works - - 23/2/05	flaginac +	flaginac +	flaginac +	—	
(B 5) 3. Collected just above intake - - 6/3/05	flaginac +	flaginac +	flaginac +	—	
(B 57) 4. Collected 12 feet above intake - 16/3/05	flaginac +	flaginac +	flagin +	—	
(B 93) 5. Collected 12 feet above intake - 22/3/05	flaginac +	flaginac +	flaginac +	—	
(B 139) 6. Collected 12 feet above intake - 30/3/05	flaginac +	flaginac +	flaginac +	flagac +	—
(B 161) 7. Collected 200 yards above intake - 3/4/05	flagac +	flaginac +	flaginac +	flaginac +	—
(B 187) 8. Collected 220 yards above intake - 10/4/05	flaginac +	flaginac +	flaginac +	flagac +	—
(B 205) 9. Collected 350 yards above intake - 17/4/05	flaginac +	flaginac +	flaginac +	—	
(B 234) 10. Collected 200 yards above intake 1/5/05	flaginac +	flaginac +	flaginac +	flaginac +	—
(B 270) 11. Collected ½ mile above intake - 15/5/05	flaginac +	flaginac +	flaginac +	flaginac +	—

TABLE II.

PIKE DRAIN WATER.

NUMBER OF B. COLI (OR COLI-LIKE MICROBES).

Description of the Sample.	+ 100 c.c. of water.	+ 10 c.c. of water.	+ 1 c.c. of water.	+ ·1 c.c. of water.	+ ·01 c.c. of water.
Pipe Drain Water.					
(10) 1. Collected 100 yards above intake - 20/2/05	flaginac +	flaginac +	flagin +	flaginac +	—
(21) 2. Collected at inlet grid. 23/2/05 -	flaginac +	flagin +	flaginac +	flaginac +	—
(26) 3. Collected 50 yards above inlet - - 25/2/05	flaginac +	flagac +	flaginac +	flagin +	—
(B 8) 4. Collected 12 feet above intake - - 7/3/05	flaginac +	flag +	flaginac +	flaginac +	—
(B 64) 5. Collected 6 feet above intake - - 17/3/05	flaginac +	flaginac +	flaginac +	—	
(B 94) 6. Collected 12 feet above intake - 22/3/05	flaginac +	flaginac +	flaginac +	—	
(B 141) 7. Collected 12 feet above intake - 30/3/05	flaginac +	flaginac +	flaginac +	flin +	—
(B 162) 8. Collected 12 feet above intake - 3/4/05	flaginac +	flaginac +	flaginac +	—	
(B 185) 9. Collected 34 yards above intake - - 10/4/05	flaginac +	flaginac +	O +	—	
(B 206) 10. Collected 150 yards above intake 17/4/05	flaginac +	flaginac +	flaginac +	—	
(B 235) 11. Collected 25 yards above intake - 1/5/05	flagac +	flaginac +	flaginac +	—	
(B 269) 12. Collected 150 yards above intake 15/5/05	flaginac +	flaginac +	flaginac +	flaginac +	—

* To express the results of sub-cultural tests of the coli-like microbes isolated in pure culture, the word "flaginac" is used in the following sense:—

F L = fluorescence in neutral-red broth cultures (48 hrs. at 37° C).
A G = acid and gas in lactose peptone cultures (48 hrs. at 37° C).
I N = indol formation in peptone water cultures (5 days at 37° C).
A C = acidity and clotting of litmus milk cultures (5 days at 37° C).

The word "flaginac" thus indicates that a microbe was indistinguishable, as regards the tests employed, from typical B. coli. When the letters are placed in brackets an incomplete reaction is indicated. The absence of a character is expressed by the omission (or deletion) of the letters chosen to indicate that attribute. When the sign "O" occurs, it means that beyond forming gas in glucose gelatine shake-cultures, the microbe yielded negative results with all the other tests.

TABLE III.

RIVER WITHAM WATER.

NUMBER OF B. COLI (OR COLI-LIKE MICROBES)

Description of the Sample.	Number of B. Coli (or coli-like microbes).					
	+ 100 c.c. of water.	+ 10 c.c. of water.	+ 1 c.c. of water.	+ ·1 c.c. of water.	+ ·01 c.c. of water.	·001 c.c. of water.
River Witham Water.						
(15) 1. Midway between C. and P. intakes - 21/2/05	flaginac +	flaginac +	—			
(27) 2. Midway between C. and P. intakes - 25/2/05	flaginac +	flaginac +	—			
(B 48) 3. Midway between C. and P. intakes 15/3/05	flaginac +	flaginac +	flin +	—		
(B 95) 4. 100 yards above entrance of Pike drain. 22/3/05*	flaginac +	flaginac +	flaginac +	flagin (ac) +	—	
(B 148) 5. Midway between C. and P. intakes 31/3/05	flagac +	flaginac +	—			
(B 163) 6. Midway between C. and P. intakes 3/4/05	(fl) agin +	flaginac +	—			
(B 186) 7. Midway between C. and P. intakes 10/4/05	flaginac +	flaginac +	—			
(B 207) 8. Midway between C. and P. intakes 17/4/05	flaginac +	flaginac +	flaginac +	—		
(B 236) 9. Midway between C. and P. intakes 1/5/05	flaginac +	flaginac +	flagin +	—		
(B 254) 10. Midway between C. and P. intakes 8/5/05	flaginac +	flaginac +	flin +	—		
(B 262) 11. Midway between C. and P. intakes 11/5/05	flaginac +	flaginac +	flaginac +	—		
(B 272) 12. Midway between C. and P. intakes 16/5/05	flaginac +	(ag) +	—			
(B 281) 13. Midway between C. and P. intakes 22/5/05	flaginac +	flaginac +	—			
(B 291) 14. Midway between C. and P. intakes 29/5/05	flaginac +	—				
(B 300) 15. Midway between C. and P. drain - 5/6/05	flaginac +	flagac +	—			
(B 309) 16. Midway between C. and P. drain - 15/6/05	flaginac +	flaginac +	—			
(B 314) 17. Midway between C. and P. drain - 19/6/05	flaginac +	flaginac +	fl +	flag +	—	
(B 352) 18. Midway between C. and P. drain - 19/7/05	flaginac +	(fl) (ag) +	(fl) (ag) +	O +	—	
(B 357) 19. Midway between C. and P. drain - 27/7/05	(fl) ag +	flaginac +	flaginac +	—		
(360) 20. Midway between C. and P. drain - 8/8/05	(fl) (ag) +	(fl) (ag) +	flaginac +	O +	—	
(363) 21. Raw water being pumped from Witham. - 17/8/05	flaginac +	flagac +	(fl) (ag) +	(fl) +	—	
(366) 22. Raw water being pumped from Witham. - 22/8/05	flaginac +	(fl) (ag) +	(fl) (ag) +	—		
(372) 23. Witham water - - - - - 5/9/05	flaginac +	flaginac +	flaginac +	—		
(378) 24. Witham water - - - - - 19/9/05	flaginac +	flag +	(fl) ag +	—		
(385) 25. Collected at intake - - - - 3/10/05	(fl) (ag) (ac) +	flaginac +	(fl) aginac +	—		
(392) 26. Collected above the intake - - 17/10/05	flaginac +	flaginac +	(fl) aginac +	—		
(398) 27. Witham water - - - - - 31/10/05	flaginac +	flaginac +	—			
(411) 28. Collected at intake - - 14/11/05	flaginac +	flaginac +	flaginac +	flaginac +	flaginac +	
(416) 29. Collected at intake - - - - 22/11/05	flaginac +	flaginac +	—			
(425) 30. Collected at intake - - - - 5/12/05	flaginac +	flaginac +	flaginac +	—		
(435) 31. Collected at intake - - - -	(fl) +	flaginac +	flaginac +	—		

* This sample was collected in too shallow water, and contained some suspended matter derived probably from the bed of the river.

TABLE IV.

HARTSHOLME WATER.

NUMBER OF B. COLI (OR COLI-LIKE MICROBES).

Description of the Sample.	Number of B. Coli (or coli-like microbes).				
	+ 100 c.c. of water.	+ 10 c.c. of water.	+ 1 c.c. of water.	+ ·1 c.c. of water.	+ ·01 c.c. of water.
Hartsholme Water.					
(24) 1. Collected at entrance to conduit - - 24/2/05	flaginac +	flaginac +	—		
(B 26) 2. Collected at entrance to conduit - 10/3/05	flaginac +	flaginac +	—		
(B 47) 3. Collected at entrance to conduit - 15/3/05	flaginac +	flaginac +	—		
(B 133) 4. Collected at entrance to conduit - 29/3/05	flaginac +	flaginac +	—		
(B 176) 5. Collected at entrance to conduit - 7/4/05	flaginac +	flaginac +	—		
(B 200) 6. Collected at entrance to conduit - 14/4/05	flaginac +	flaginac +	—		
(B 220) 7. Collected at entrance to conduit - 20/4/05	flaginac +	flaginac +	—		
(B 248) 8. Collected from opening in conduit - at works. 5/5/05	flaginac +	—			
(B 256) 9. Collected at entrance to conduit - 9/5/05	flaginac +	flaginac +	(ag) +	—	
(B 266) 10. Collected from opening in conduit at works. 12/5/05	flagin +	—			
(B 278) 11. Collected at entrance to conduit - 19/5/05	flaginac +	flaginac +	—		
(B 290) 12. Collected from opening in conduit at works. 26/5/05	—				
(452) 13. Hartsholme water - - - - - 15/1/06	flaginac +	flaginac +	flaginac +	—	

TABLE V.

BALLAST PIT WATER.

NUMBER OF B. COLI (OR COLI-LIKE MICROBES).

Description of the Sample.	Number of B. Coli (or coli-like microbes)				
	+ 100 c.c. of water.	+ 10 c.c. of water.	+ 1 c.c. of water.		
Ballast Pit Water.					
1. Collected at entrance to conduit - 22/2/05	fl +	—			
(B 299) 2. Collected at opening in Culvert at works. 2/6/05	—				
(B 303) 3. Collected at opening in tunnel - 6/6/05	—				
(B 313) 4. Collected from Cockpit - - 16/6/05	flaginac +	—			
(B 319) 5. Collected from Cockpit - - - 23/6/05	flaginac +	flag(in)ac +	—		
(B 348) 6. Collected from Weir at works - 14/7/05	fl +	—			
(B 356) 7. Collected from Weir at works - 26/7/05	—				
(B 369) 8. Ballast Pit water - - - - 29/8/05	—				
(375) 9. Collected from Culvert - - - 13/9/05	—				
(381) 10. Ballast Pit water - - - - 26/9/05	—				
(390) 11. Ballast Pit water - - - - 10/10/05	—				
(397) 12. Ballast Pit water - - - - 25/10/05	—				
(407) 13. Ballast Pit water - - - - 8/11/05	(fl) (ag) +	—			
(421) 14. Ballast Pit water - - - - 29/11/05	—				
(450) 15. Ballast Pit water - - - - 15/1/06	—				
(507) 16. Ballast Pit water (*unfiltered*) - - 25/4/06	—				
(525) 17. Ballast Pit water (*filtered*) - - 16/7/06	(fl) +	—			

TABLE VI.

CROSSCLIFFE RESERVOIR WATER.

Number of B. Coli (or Coli-like Microbes).

Description of the Sample.	Number of B. Coli (or coli-like microbes).				
	+ 100 c.c. of water.	+ 10 c.c. of water.	+ 1 c.c. of water.	+ ·1 cc. of water.	
Crosscliffe Reservoir Water.					
(A 5) 1. Crosscliffe Reservoir water - - 12/2/05. 6 a.m.	—				
(A 4) 2. Crosscliffe Reservoir water - - 12/2/05. 6 p.m.	—				
(A 8) 3. Crosscliffe Reservoir water - - 13/2/05. 6 a.m.	—				
(A 7) 4. Crosscliffe Reservoir water - - 13/2/05. 6 p.m.	—				
(A 11) 5. Crosscliffe Reservoir water - - 14/2/05	—				
(11) 6. Crosscliffe Reservoir water - - - 20/2/05	—				
(B 2) 7. Crosscliffe Reservoir water - - 4/3/05	—				
(B 14) 8. Crosscliffe Reservoir water - - 8/3/05	—				
(B 56) 9. Crosscliffe Reservoir water - - 16/3/05	—				
(B 77) 10. Crosscliffe Reservoir water - - 18/3/05	—				
(B 115) 11. Crosscliffe Reservoir water - - 25/3/05	—				
(B 154) 12. Crosscliffe Reservoir water - - 1/4/05	—				
(B 168) 13. Crosscliffe Reservoir water - - 5/4/05	—				
(B 192) 14. Crosscliffe Reservoir water - - 12/4/05	—				
(B 213) 15. Crosscliffe Reservoir water - - 19/4/05	—				
(B 225) 16. Crosscliffe Reservoir water - - 27/4/05	—				
(B 240) 17. Crosscliffe Reservoir water - - 3/5/05	—				
(B 265) 18. Crosscliffe Reservoir water - - 12/5/05	flaginac +	—			
(B 276) 19. Crosscliffe Reservoir water - - 18/5/05	—				
(B 284) 20. Crosscliffe Reservoir water - - 24/5/05	flaginac +	—			
(B 297) 21. Crosscliffe Reservoir water - - 1/6/05	flaginac +	—			
(B 304) 22. Crosscliffe Reservoir water - - 6/6/05	flagac +	flaginac +	flaginac +	—	
(B 311) 23. Crosscliffe Reservoir water - - 16/6/05	flagin +	flagin +	—		
(B 317) 24. Crosscliffe Reservoir water - - 22/6/05	flaginac +	flaginac +	—		
(B 324) 25. Crosscliffe Reservoir water - - 28/6/05	flaginac +	flaginac +	—		
(B 327) 26. Crosscliffe Reservoir water - - 3/7/05	flaginac +	flinac +	—		
(B 329) 27. Crosscliffe Reservoir water - - 4/7/05	flaginac +	—			
(B 330) 28. Crosscliffe Reservoir water - - 5/7/05	flaginac +	flaginac +	—		
(B 333) 29. Crosscliffe Reservoir water - - 6/7/05	flaginac +	—			
(B 337) 30. Crosscliffe Reservoir water - - 10/7/05	—				
(B 340) 31. Crosscliffe Reservoir water - - 11/7/05	—				
(B 342) 32. Crosscliffe Reservoir water - - 12/7/05	—				
(B 346) 33. Crosscliffe Reservoir water - - 13/7/05	—				
(B 349). Crosscliffe Reservoir water - - 15/7/05	—				
(B 350). Crosscliffe Reservoir water - - 17/7/05	—				

TABLE VII.

WESTGATE RESERVOIR WATER.

Number of B. Coli (or Coli-like Microbes).

Description of the Sample.	Number of B. Coli (or coli-like microbes).			
	+ 100 c.c. of water.	+ 10 c.c. of water.	+ 1 c.c. of water.	+ ·1 c.c. of water.
Westgate Reservoir Water.				
(A 9) 1. Westgate Reservoir water - - 13/2/05	—			
(A 13) 2. Westgate Reservoir water - - 14/2/05	—			
(A 15) 3. Westgate Reservoir water - - 15/2/05	—			
(1) 4. Westgate Reservoir water - - - 19/2/05	—			
(B 3) 5. Westgate Reservoir water - - 5/3/05	—			
(B 15) 6. Westgate Reservoir water - - 8/3/05	—			
(B 34) 7. Westgate Reservoir water - - 12/3/05	—			
(B 51) 8. Westgate Reservoir water - - 15/3/05	fl +	—		
(B 79) 9. Westgate Reservoir water - - 19/3/05	—			
(B 118) 10. Westgate Reservoir water - - 26/3/05	flagin +	—		
(B 155) 11. Westgate Reservoir water - - 2/4/05	flaginac +	—		
(B 171) 12. Westgate Reservoir water - - 5/4/05	flaginac +	—		
(B 195) 13. Westgate Reservoir water - - 12/4/05	—			
(B 216) 14. Westgate Reservoir water - - 19/4/05	—			
(B 223) 15. Westgate Reservoir water - - 26/4/05	—			
(B 243) 16. Westgate Reservoir water - - 3/5/05	flaginac +	—		
(B 260) 17. Westgate Reservoir water - - 10/5/05	flaginac +	—		
(B 275) 18. Westgate Reservoir water - - 17/5/05	flaginac +	flaginac +	—	
(B 286) 19. Westgate Reservoir water - - 24/5/05	(fl) +	flagin +	—	
(B 295) 20. Westgate Reservoir water - - 31/5/05	flaginac +	flaginac +	flaginac +	—
(B 306) 21. Westgate Reservoir water - - 7/6/05	flaginac +	flaginac +	flin +	—
(B 308) 22. Westgate Reservoir water - - 14/6/05	fl +	flaginac +	—	
(B 316) 23. Westgate Reservoir water - - 21/6/05	flaginac +	flaginac +	flaginac +	—
(B 321) 24. Westgate Reservoir water - - 23/6/05	flaginac +	flaginac +	—	
(B 322) 25. Westgate Reservoir water - - 27/6/05	flaginac +	flaginac +	—	
(B 328) 26. Westgate Reservoir water - - 4/7/05	flaginac +	flagin +	—	
(B 332) 27. Westgate Reservoir water - - 5/7/05	flaginac +	flaginac +	(fl) +	—
(B 334) 28. Westgate Reservoir water - - 6/7/05	flaginac +	flaginac +	flaginac +	—
(B 335) 29. Westgate Reservoir water - - 7/7/05	flagin +	flaginac +	—	
(B 338) 30. Westgate Reservoir water - - 10/7/05	—			
(B 341) 31. Westgate Reservoir water - - 11/7/05	—			
(B 344) 32. Westgate Reservoir water - - 12/7/05	—			
(B 345) 33. Westgate Reservoir water - - 13/7/05	flaginac +	—		
(B 347) 34. Westgate Reservoir water - - 14/7/05	—			

TABLE VIII.

FILTERED WATER TANK AND WELLS OF BEDS 1 TO 6.

Number of B. Coli (or Coli-like Microbes).

Description of the Sample.		Number of B. Coli (or coli-like microbes).				
		+ 100 c.c. of water.	+ 10 c.c. of water.	+ 1 c.c. of water.		
(3) 1. Well of bed No. 5 - - - -	19/2/05	flaginac +	—			
(4) 2. Well of bed No. 4 - - - -	19/2/05	flaginac +	—			
(5) 3. Filtered water tank - - - -	19/2/05	flaginac +	—			
(7) 4. Well of bed No. 3 - - - -	20/2/05	flaginac +	—			
(8) 5. Filtered water tank - - - -	20/2/05	flaginac +	—			
(9) 6. Well of bed No. 1 - - - -	20/2/05	flagin +	—			
(12) 7. Well of bed No. 2 - - - -	20/2/05	—				
(13) 8. Filtered water tank - - - -	21/2/05	—				
(16) 9. Filtered water tank - - - -	22/2/05	—				
(19) 10. Well of bed No. 5 - - - -	22/2/05	—				
(22) 11. Well of bed No. 6 - - - -	23/2/05	—				
(A) 12. Well of bed No. 2 - - - -	25/2/05	flaginac +	—			
(B) 13. Well of bed No. 3 - - - -	25/2/05	flaginac +	—			
(C) 14. Well of bed No. 4 - - - -	25/2/05	flaginac +	—			
(B 4) 15. Well of bed No. 1 - - - -	6/3/05	flaginac +	—			
(B 6) 16. Filtered water tank - - -	7/3/05	—				
(B 7) 17. Well of bed No. 2 - - - -	7/3/05	flaginac +	—			
(B 13) 18. Well of bed No. 3 - - - -	8/3/05	flaginac +	flaginac +	—		
(B 20) 19. Well of bed No. 4 - - - -	10/3/05	fl +	—			
(B 49) 20. Well of bed No. 5 - - - -	15/3/05	—				
(B 65) 21. Well of bed No. 1 - - - -	17/3/05	—				
(B 66) 22. Filtered water tank - - -	17/3/05	flag +	—			
(B 72) 23. Well of bed No. 2 - - - -	18/3/05	—				
(B 80) 24. Well of bed No. 3 - - - -	20/3/05	flaginac +	—			
(B 86) 25. Well of bed No. 4 - - - -	21/3/05	fl(ag)in +	—			
(B 92) 23. Well of bed No. 5 - - - -	22/3/05	—				
(B 101) 27. Filtered water tank - - -	23/3/05	—				
(B 102) 28. Well of bed No. 6 - - -	23/3/05	—				
(B 120) 29. Filtered water tank - - -	27/3/05	—				
(B 121) 30. Well of bed No. 1 - - -	27/3/05	—				
(B 132) 31. Well of bed No. 2 - - -	29/3/05	—				
(B 140) 32. Well of bed No. 4 - - -	30/3/05	—				
(B 147) 33. Well of bed No. 5 - - -	31/3/05	flagac +	—			

TABLE IX.

MAIN TAP SAMPLES, COLLECTED FROM A LARGE NUMBER OF PLACES WITHIN THE AREA OF SUPPLY

NUMBER OF B. COLI (OR COLI-LIKE MICROBES).

Description of the Sample.	Number of B. Coli (or coli-like microbes).				
	+ 100 c.c. of water.	+10 c.c. of water.	+ 1 c.c. of water.		
Main Tap Samples.					
(23) 1. Creston Villas - - - - - 23/2/05	flaginac +	—			
(25) 2. Creston Villas - - - - - 24/2/05	flaginac +	flag +	—		
(B 9) 3. 5, Fairfax Street, Bracebridge - - 7/3/05	flaginac +	—			
(B 10) 4. 60, Waterloo Street, New Boultham 7/3/05	—				
(B 11) 5. Ward's Passage, Dane's Gate - - 7/3/05	—				
(B 12) 6. 1, Eleanor Street (off Bargate) - 7/3/05	—				
(B 16) 7. 1, Temperance Place - - - 8/3/05	fl(ag) +	—			
(B 17) 8. 3, Alexandra Terrace - - - 8/3/05	—				
(B 18) 9. 23, Sewell's Walk - - - - 8/3/05	flaginac +	—			
(B 19) 10. 14, Cranwell Street - - - 8/3/05	—				
(B 22) 11. 16, Earl's Street - - - - 9/3/05	—				
(B 23) 12. 66, St. Andrew's Street - - - 9/3/05	—				
(B 24) 13. 10, Picton Street, N. Boultham - 9/3/05	flagin +	flagac +	—		
(B 25) 14. 1, Hardinge Street, N. Boultham - 9/3/05	—				
(B 28) 15. Portland Arms, Portland Street - 10/3/05	—				
(B 29) 16. 18, Chaplin Street - - - 10/3/05	—				
(B 31) 17. 28, Alfred Street - - - - 10/3/05	—				
(B 32) 18. 12, Peel Street - - - - 10/3/05	—				
(B 37) 19. Otters' Cottages, Newark Road - 13/3/05	—				
(B 38) 20. 10, Stanley Street, Newark Road - 13/3/05	—				
(B 39) 21. 27, Millon Street, Newark Road - 13/3/05	—				
(B 40) 22. 13, Webb Street - - - - 13/3/05	flaginac +	fl (ag) +	—		
(B 41) 23. 37, Cheviot Street, Monk's Road - 14/3/05	—				

TABLE IX—*continued.*

MAIN TAP SAMPLES, COLLECTED FROM A LARGE NUMBER OF PLACES WITHIN THE AREA OF SUPPLY.

NUMBER OF B. COLI (OR COLI-LIKE MICROBES).

Description of the Sample.	Number of B. Coli (or coli-like microbes).				
	+ 100 c.c. of water.	+ 10 c.c. of water.	+ 1 c.c. of water.		
(B 42) 24. 39, Cheviot Street, Monk's Road - 14/3/05	flaginac +	—			
(B 44) 25. 5, Colerby Street - - - - 14/3/05	—				
(B 45) 26. 31, Broadgate - - - - 14/3/05	—				
(B 52) 27. Occupation Road, Burton Road - 15/3/05	—				
(B 53) 28. 95, Milne Road, Burton Road - 15/3/05	—				
(B 54) 29. Corner Yarborough Road and Burton Road. 15/3/05	flaginac +	—			
(B 55) 30. 3, St. Michael's Terrace - - 15/3/05	—				
(B 59) 31. Kent House, Riseholme Road - 16/3/05	—				
(B 60) 32. 89, Newport - - - - - 16/3/05	—				
(B 61) 33. 58, Rasen Lane - - - - 16/3/05	—				
(B 62) 34. 4, St. Paul's Lane - - - - 16/3/05	—				
B 68) 35. 24, Ripon's Street - - - 17/3/05	—				
(B 69) 36. 11, Thesiger Street - - - 17/3/05	—				
(B 70) 37. 129, Canwick Road - - - 17/3/05	—				
(B 71) 38. 41, South Park - - - - 17/3/05	fl +	fl +	—		
(B 73) 39. 13, Great Northern Terrace - - 18/3/05	fl +				
(B 74) 40. 17, Clifton Street - - - - 18/3/05	—				
(B 75) 41. 63, Coultham Street - - - 18/3/05	—				
(B 76) 42. 23, Gouling Street - - - 18/3/05	flaginac +	—			
(B 82) 43. 17, Gresham Street - - - 20/3/05	—				
(B 83) 44. 123, Newland Street West - - 20/3/05	flag +	—			
(B 84) 45. 87, Carrholme Road - - - 20/3/05	—				
(B 85) 46. 2, Brayford Head - - - - 20/3/05	—				
(B 88) 47. *Repetition of* (B 24) 13 - - - 21/3/05	flagin(ac) +	—			

TABLE IX.

MAIN TAP SAMPLES, COLLECTED FROM A LARGE NUMBER OF PLACES WITHIN THE AREA OF SUPPLY.

NUMBER OF B. COLI (OR COLI-LIKE MICROBES).

Description of the Sample.	Number of B. Coli (or coli-like microbes).				
	+100 c.c. of water.	+10 c.c. of water.	+1 c.c. of water.	+·1 c.c. of water.	+·01 c.c. of water.
(B 89) 48. *Repetition of* (B 54) 29 - - - 21/3/05	—				
(B 90) 49. *Repetition of* (B 16) 7 - - - 21/3/05	fl +	—			
(B 91) 50. *Repetition of* (B 40) 22 - - - 22/3/05	flagac +	—			
(B 97) 51. *Repetition of* (B 42) 24 - - - 22/3/05	—				
(B 98) 52. Williams' Square Bridge Street - 22/3/05	—				
(B 99) 53. *Repetition of* (B 73) 39 - - - 22/3/05	flaginac +	—			
(B 100) 54. *Repetition of* (B 76) 42 - - 22/3/05	—				
(B 103) 55. *Repetition of* (B 9) 3 - - - 23/3/05	—				
(B 104) 56. 153, Bracebridge - - - - 23/3/05	—				
(B 105) 57. *Repetition of* (B 71) 38 - - 23/3/05	—				
(B 106) 58. *Repetition of* (B 18) 9 - - - 23/3/05	—				
(B 109) 59. 145, West Parade - - - 24/3/05	flagin +	—			
(B 110) 60. Eagle House, H. Road - - 24/3/05	—				
(B 111) 61. 41, Richmond Road - - - 25/3/05	—				
(B 112) 62. 13, Yarborough Road - - - 25/3/05	—				
(B 113) 63. Sandfield House, Crosscliffe Hill - 25/3/05	—				
(B 114) 64. Cottage at Crosscliffe Reservoir - 25/3/05	—				
(B 116) 65. 4, High Street - - - - 25/3/05	—				
(B 117) 66. Riversmere, Colgrave Street - 25/3/05	—				
(B 123) 67. Last house in Greetwell Road - 27/3/05	—				
(B 124) 68. St. Giles' Farm, Wragby Road - 27/3/05	—				
(B 125) 69. 10, Langworth Gate - - - 27/3/05	—				
(B 126) 70. Nightingale Inn, Nettleham Road 27/3/05	—				
(B 128) 71. 9, Edna Street - - - - 28/3/05	—				

TABLE IX—*continued.*

MAIN TAP SAMPLES, COLLECTED FROM A LARGE NUMBER OF PLACES WITHIN THE AREA OF SUPPLY.

NUMBER OF B. COLI (OR COLI-LIKE MICROBES).

Description of the Sample.	Number of B. Coli (or coli-like microbes).				
	+100 c.c. of water.	+10 c.c. of water.	+1 c.c. of water.	+·1c.c. of water.	+·01 c.c. of water.
(B 129) 72. 20, Martin Street - - - 28/3/05	—				
(B 130) 73. 35, Norris Street - - - - 28/3/05	flag +	flagin +	—		
(B 131) 74. 6, Lancaster Place - - - 28/3/05	—				
(B 135) 75. 12, Newton Street - - - 29/3/05	—				
(B 136) 76. Peart's Cottage, Norman Street - 29/3/05	—				
(B 137) 77. Gadsby Court - - - - 29/3/05	—				
(B 138) 78. Napoleon Place - - - - 29/3/05	flaginac +	—			
(B 143) 79. 38, Queen Street - - - - 30/3/05	—				
(B 144) 80. 5, Knight's Terrace - - - 30/3/05	—				
(B 145) 81. 38, Little Bargate Street - - 30/3/05	—				
(B 146) 82. 21, High Street - - - - 30/3/05	—				
(B 150) 83. 19, Tennyson Street - - - 31/3/05	—				
(B 151) 84. 11, Ely Street - - - - 31/3/05	—				
(B 152) 85. 17, May Crescent - - - 31/3/05	—				
(B 153) 86. 6, Yarborough Terrace - - 31/3/05	—				
(B 156) 87. 16, Altham Terrace - - - 3/4/05	—				
(B 157) 88. 7, Derby Street - - - - 3/4/05	—				
(B 158) 89. 5, Weir Street - - - - 3/4/05	—				
(B 159) 90. Western Lodge, St. Catherine's Road. 3/4/05	—				
(B 165) 91. *Repetition of* (B 40) 22 and (B 91) 50. 4/4/05	—				
(B 166) 92. 29, Sydney Street - - - 4/4/05	—				
(B 169) 93. *Repetition of* (B 73) 39 and (B 99) 53. 5/4/05	—				
(B 170) 94. *Repetition of* (B 16) 7 and (B 90) 49. 5/4/05	—				
(B 173) 95. *Repetition of* (B 83) 44 - - 6/4/05	—				

TABLE IX—*continued.*

MAIN TAP SAMPLES, COLLECTED FROM A LARGE NUMBER OF PLACES WITHIN THE AREA OF SUPPLY

NUMBER OF B. COLI (OR COLI LIKE MICROBES).

Description of the Sample.	Number of B. Coli (or coli-like microbes).				
	+ 100 c.c. of water.	+ 10 c.c. of water	+ 1 c.c. of water.	+ ·1 c.c. of water.	+ ·01 c.c. of water.
(B 174) 96. *Repetition of* (B 109) 59 - - 6/4/05	—				
(B 175) 97. Scullery at workhouse - - - 6/4/05	fl +	—			
(B 180) 98. *Repetition of* (B 24) 13 and (B 88) 47. 7/4/05	—				
(B 182) 99. *Repetition of* (B 175) 97 - - 8/4/05	—				
(B 189) 100. 13, Vernon Street - - - 11/4/05	—				
(B 190) 101. 21, Anchor Street - - - 11/4/05	fl +	—			
(B 193) 102. *Repetition of* (B 130) 73 - - 12/4/05	—				
(B 194) 103. *Repetition of* (B 138) 78 - - 12/4/05	—				
(B 197) 104. 14, Napier Street - - - 13/4/05	—				
(B 198) 105. 6, Arboretum View - - - 13/4/05	—				
(B 201) 106. 11, Swanpool Street - - - 14/4/05	—				
(B 210) 107. Blandell's Court - - - 18/4/05	—				
(B 211) 108. 9, Hall's Yard - - - - 18/4/05	—				
(B 214) 109. 52, Bail Gate - - - - 19/4/05	—				
(B 215) 110. 10, Chapel Lane - - - 19/4/05	—				
(B 217) 111. 23, Featherley Place - - - 20/4/05	—				
(B 218) 112. Chemist's shop, corner High Street and Henley Street. 20/4/05	fl +	—			
(B 221) 113. St. Martin's Row - - - 26/4/05	—				
(B 222) 114. Brumitts Court - - - - 26/4/05	—				
(B 226) 115. 5, Shakespeare Street - - 27/4/05	—				
(B 227) 116. Ashton's Court, High Street - 27/4/05	—				
(B 230) 117. 376, High Street - - - 28/4/05	—				
(B 241) 118. 22, Mint Lane - - - - 3/5/05	—				
(B 242) 119. 33½, Hun Gate - - - - 3/5/05	agac +	—			
(B 245) 120. Glory Hole - - - - 4/5/05	—				

TABLE IX—*continued.*

MAIN TAP SAMPLES, COLLECTED FROM A LARGE NUMBER OF PLACES WITHIN THE AREA OF SUPPLY.

NUMBER OF B. COLI (OR COLI-LIKE MICROBES).

Description of the Sample.	Number of B. Coli (or coli-like microbes).				
	+ 100 c.c. of water.	+ 10 c.c. of water.	+ 1 c.c. of water.	+ ·1 c.c. of water.	+ ·01 c.c. of water.
(B 246) 121. 6, Unity Square - - - 4/5/05	—				
(B 249) 122. 7, Mill Lane - - - - 5/5/05	—				
(B 250) 123. 2, Water Lane - - - 5/5/05	—				
(B 257) 124. *Repetition of* (B 218) 112 - - 9/5/05	—				
(B 263) 125. *Repetition of* (B 190) 101 - - 11/5/05	fl (ag) +	—			
(B 267) 126. *Repetition of* (B 242) 119 - - 12/5/05	flaginac +	—			
(B 273) 127. *Repetition of* (B 190) 101 and (B 263) 125. 16/5/05	—				
(B 280) 128. *Repetition of* (B 242) 119 and (B 267) 126. 19/5/05	flaginac +	—			
(B 288) 129. *Repetition of* (B 242) 119, (B 267) 126 and (B 280) 128. 25/5/05	flaginac +	—			
(B 343) 130. *Repetition of* (B 288) 129, (B 242) 119, (B 267) 126, (B 280) 128. 12/7/05	—				
(482). Sample from Waterworks Office tap - 8/3/06	—				
(485). Sample from tap in Dixon's Chemist Shop, High Street. 15/3/06	—				
(487). Sample from tap in Municipal Technical School. 19/3/06	—				
(489). Sample from Barham's Shop, Silver Street. 22/3/06	—				
(492). Sample from tap in Police Yard - - 26/3/06	—				
(495). Sample from Taylor's Court, High Street. 29/3/06	—				
(497). Sample from the Yard, Waterside - 2/4/06	—				
(499). Sample from Corporation Office - - 6/4/06	—				
(500). Sample from tap, Danes Gate - - 9/4/06	—				
(505). Sample from Goulson's tap, Waterside 23/4/06	—				
(508). Sample from Waterworks Store Yard, Brayford Side. 26/4/06	—				
(510). Sample from 57, St. Catherine's Grove 30/4/06	flaginac +	—			
(512). Sample from Cooper's tap, High Street 3/5/06	—				
(514). Sample from 6, Muck Lane - - 8/5/06	—				

TABLE X.

MAIN TAP WATER, RISING MAIN AT WORKS.

NUMBER OF B. COLI (OR COLI-LIKE MICROBES).

Description of the Sample.	Number of B. Coli (or coli-like microbes).				
	+ 100 c.c. of water.	+ 10 c.c. of water.	+ 1 c.c. of water.	+ ·1 c.c. of water.	+ ·01 c.c. of water.
(A 6) 1. Main tap at works - - - - 12/2/05	flaginac +	—			
(A 10) 2. Main tap at works - - - - 13/2/05	flaginac +	flagin +	—		
(A 12) 3. Main tap at works - - - - 14/2/05	flaginac +	—			
(A 16) 4. Main tap at works - - - - 15/2/05	flaginac +	—			
(A 17) 5. Main tap at works - - - - 17/2/05	flaginac +	flaginac +	—		
(B 1) 6. Main tap at works - - - - 4/3/05	—				
(B 21) 7. Main tap at works - - - - 9/3/05	—				
(B 27) 8. Main tap at works - - - - 10/3/05	flaginac +	—			
(B 36) 9. Main tap at works - - - - 13/3/05	—				
(B 46) 10. Main tap at works - - - 14/3/05	—				
(B 50) 11. Main tap at works - - - 15/3/05	—				
(B 58) 12. Main tap at works - - - 16/3/05	—				
(B 67) 13. Main tap at works - - - 17/3/05	—				
(B 78) 14. Main tap at works - - - 19/3/05	—				
(B 81) 15. Main tap at works - - - 20/3/05	—				
(B 87) 16. Main tap at works - - - 21/3/05	—				
(B 96) 17. Main tap at works - - - 22/3/05	—				
(B 107) 18. Main tap at works - - - 23/3/05	—				
(B 108) 19. Main tap at works - - - 24/3/05	—				
(B 119) 20. Main tap at works - - - 26/3/05	—				
(B 122) 21. Main tap at works - - - 27/3/05	flaginac +	—			
(B 127) 22. Main tap at works - - - 28/3/05	—				
(B 134) 23 Main tap at works - - - 29/3/05	—				
(B 140) 24. Main tap at works - - - 31/3/05	—				

TABLE X—*continued.*

MAIN TAP WATER, RISING MAIN AT WORKS.

NUMBER OF B. COLI (OR COLI-LIKE MICROBES).

Description of the Sample.	Number of B. Coli (or coli-like microbes).				
	+ 100 c.c. of water.	+ 10 c.c. of water.	+ 1 c.c. of water.	+ ·1 c.c. of water.	+ ·01 c.c. of water.
(B 160) 25. Main tap at works - - - 3/4/05	—				
(B 167) 26. Main tap at works - - - 5/4/05	flagac +	—			
(B 172) 27. Main tap at works - - - 6/4/05	—				
(B 177) 28. Main tap at works - - - 7/4/05	—				
(B 181) 29. Main tap at works - - - 8/4/05	—				
(B 183) 30. Main tap at works - - - 9/4/05	—				
(B 184) 31. Main tap at works - - - 10/4/05	fl +	—			
(B 188) 32. Main tap at works - - - 11/4/05	fl +	—			
(B 191) 33. Main tap at works - - - 12/4/05	fl +	flaginac +	—		
(B 196) 34. Main tap at works - - - 13/4/05	—				
(B 199) 35. Main tap at works - - - 14/4/05	—				
(B 202) 36. Main tap at works - - - 15/4/05	—				
(B 203) 37. Main tap at works - - - 16/4/05	fl +	—			
(B 204) 38. Main tap at works - - - 17/4/05	—				
(B 212) 39. Main tap at works - - - 19/4/05	—				
(B 219) 40. Main tap at works - - - 20/4/05	—				
(B 224) 41. Main tap at works - - - 27/4/05	—				
(B 228) 42. Main tap at works - - - 28/4/05	—				
(B 231) 43. Main tap at works - - - 29/4/05	—				
(B 232) 44. Main tap at works - - - 30/4/05	—				
(B 233) 45. Main tap at works - - - 1/5/05	—				
(B 237) 46 Main tap at works - - - 2/5/05	—				
(B 239) 47. Main tap at works - - - 3/5/05	—				
(B 244) 48. Main tap at works - - - 4/5/05	—				

TABLE X—*continued.*

MAIN TAP WATER, RISING MAIN AT WORKS.

NUMBER OF B. COLI (OR COLI-LIKE MICROBES).

Description of the Sample.	Number of B. Coli (or coli-like microbes).				
	+ 100 c.c. of water.	+ 10 c.c. of water.	+ 1 c.c. of water.	+ ·1 c.c. of water.	+ ·01 c.c. of water.
(B 247) 49. Main tap at works - - - 5/5/05	—				
(B 252) 50. Main tap at works - - - 7/5/05	—				
(B 253) 51. Main tap at works - - - 8/5/05	—				
(B 255) 52. Main tap at works - - - 9/5/05	flaginac +	—			
(B 258) 53. Main tap at works - - - 10/5/05	—				
(B 261) 54. Main tap at works - - - 11/5/05	—				
(B 264) 55. Main tap at works - - - 12/5/05	—				
(B 268) 56. Main tap at works - - - 15/5/05	fl +	—			
(B 271) 57. Main tap at works - - - 16/5/05	—				
(B 274) 58. Main tap at works - - - 17/5/05	—				
(B 277) 59. Main tap at works - - - 18/5/05	—				
(B 279) 60. Main tap at works - - - 19/5/05	—				
(B 282) 61. Main tap at works - - - 22/5/05	—				
(B 283) 62. Main tap at works - - - 23/5/05	flaginac +	—			
(B 285) 63. Main tap at works - - - 24/5/05	—				
(B 287) 64. Main tap at works - - - 25/5/05	—				
(B 289) 65. Main tap at works - - - 26/5/05	—				
(B 292) 66. Main tap at works - - - 29/5/05	—				
(B 293) 67. Main tap at works - - - 30/5/05	—				
(B 294) 68. Main tap at works - - - 31/5/05	—				
(B 296) 69. Main tap at works - - - 1/6/05	—				
(B 298) 70. Main tap at works - - - 2/6/05	—				
(B 301) 71. Main tap at works - - - 5/6/05	—				
(B 302) 72. Main tap at works - - - 6/6/05	—				

TABLE X—*continued.*

MAIN TAP WATER, RISING MAIN AT WORKS.

NUMBER OF B. COLI (OR COLI-LIKE MICROBES).

Description of the Sample.		Number of B. Coli (or coli-like microbes).				
		+ 100 c.c. of water.	+ 10 c.c. of water.	+ 1 c.c. of water.	+ ·1 c.c. of water.	+ ·01 c.c. of water.
(B 305) 73. Main tap at works - - -	7/6/05	—				
(B 307) 74. Main tap at works - - -	14/6/05	flagac +	flag +	—		
(B 310) 75. Main tap at works - - -	15/6/05	flagin (ac) +	—			
(B 312) 76. Main tap at works - - -	16/6/05	flaginac +	—			
(B 318) 77. Main tap at works - - -	22/6/05	—				
(B 320) 78. Main tap at works - - -	23/6/05	—				
(B 323) 79. Main tap at works - - -	28/6/05	—				
(B 325) 80. Main tap at works - - -	29/6/05	—				
(B 326) 81. Main tap at works - - -	30/6/05	flaginac +	—			
(B 331) 82. Main tap at works - - -	5/7/05	flaginac +	—			
(B 336) 83. Main tap at works - - -	7/7/05	(ag) (ac) +	—			
(B 339) 84. Main tap at works - - -	10/7/05	—				
(B 351) 85. Main tap at works - - -	18/7/05	fl (ag) +	flaginac +	—		
(B 353) 86. Main tap at works - - -	20/7/05	flag +	—			
(B 354) 87. Main tap at works - - -	21/7/05	(fl) +	—			
(B 355) 88. Main tap at works - - -	25/7/05	—				
(B 358) 89. Main tap at works - - -	28/7/05	—				
(359) 90. Main tap at works - - - -	8/8/05	(fl) +	(fl) +	—		
(361) 91. Main tap at works - - - -	10/8/05	(fl) +	(fl) aginac +	—		
(362) 92. Main tap at works - - - -	17/8/05	(fl) +	—			
(365) 93. Main tap at works - - - -	18/8/05	(fl) (ag) ac +	—			
(367) 94. Main tap at works - - - -	22/8/05	fl +	—			
(368) 95. Main tap at works - - - -	24/8/05	(fl) aginac +	(fl) aginac +	O +	—	
(370) 96. Main tap at works - - - -	29/8/05	flaginac +	—			

TABLE X—*continued.*

MAIN TAP WATER, RISING MAIN AT WORKS.

NUMBER OF B. COLI (OR COLI-LIKE MICROBES).

Description of the Sample.	Number of B. Coli (or coli-like microbes).				
	+ 100 c.c. of water.	+ 10 c.c. of water.	+ 1 c.c. of water.	+ ·1 c.c. of water.	+ ·01 c.c. of water.
(371) 97. Main tap at works - - - - 30/8/05	(fl) ag +	—			
(373) 98. Main tap at works - - - - 5/9/05	—				
(374) 99. Main tap at works - - - - 6/9/05	—				
(376) 100. Main tap at works - - - 13/9/05	—				
(377) 101. Main tap at works - - - 15/9/05	flaginac +	—			
(379) 102. Main tap at works - - - 19/9/05	—				
(380) 103. Main tap at works - - - 20/9/05	—				
(382) 104. Main tap at works - - - 26/9/05	—				
(383) 105. Main tap at works - - - 27/9/05	—				
(384) 106. Main tap at works - - - 28/9/05	—				
(386) 107. Main tap at works - - - 3/10/05	—				
(387) 108. Main tap at works - - - 4/10/05	—				
(389) 109. Main tap at works - - - 10/10/05	fl +	—			
(391) 110. Main tap at works - - - 11/10/05	—				
(393) 111. Main tap at works - - - 17/10/05	—				
(394) 112. Main tap at works - - - 18/10/05	—				
(395) 113. Main tap at works - - - 24/10/05	—				
(396) 114. Main tap at works - - - 25/10/05	fl (ag) ac +	—			
(400) 115. Main tap at works - - - 1/11/05	—				
(404) 116. Main tap at works - - - 3/11/05	—				
(405) 117. Main tap at works - - - 6/11/05	flagin +	fl +	—		
(406) 118. Main tap at works - - - 8/11/05	(fl) aginac +	(fl) +	—		
(408) 119. Main tap at works - - - 10/11/05	flaginac +	fl +	—		
(409) 120. Main tap at works - - - 11/11/05	flaginac +	—			

TABLE X—*continued.*

MAIN TAP WATER, RISING MAIN AT WORKS.

NUMBER OF B. COLI OR COLI-LIKE MICROBES.

Description of the Sample.	Number of B. Coli (or coli-like microbes).				
	+ 100 c.c. of water.	+ 10 c.c. of water.	+ 1 c.c. of water.	+ ·1 c.c. of water.	+ ·01 c.c. of water.
(410) 121. Main tap at works - - - 13/11/05	flaginac +	flaginac +	—		
(412) 122. Main tap at works - - - 14/11/05	flaginac +	(fl)ag(in)ac +	(fl)aginac +	(fl)aginac +	—
(413) 123. Main tap at works - - - 16/11/05	flaginac +	fl +	—		
(414) 124. Main tap at works - - - 17/11/05	flaginac +	flaginac +	—		
(415) 125. Main tap at works - - - 21/11/05	(fl) aginac +	—			
(417) 126. Main tap at works - - - 22/11/05	flaginac +	flaginac +	—		
(418) 127. Main tap at works - - - 23/11/05	(fl) ag +	—			
(419) 128. Main tap at works - - - 24/11/05	flaginac +	—			
(420) 129. Main tap at works - - - 28/11/05	flaginac +	flaginac +	—		
(422) 130. Main tap at works - - - 29/11/05	flaginac +	flaginac +	flaginac +	—	
(423) 131. Main tap at works - - - 30/11/05	flaginac +	flaginac +	flaginac +	flaginac +	—
(424) 132. Main tap at works - - - 1/12/05	flaginac +	flaginac +	flaginac +	—	
(426) 133. Main tap at works - - - 5/12/05	(fl) aginac +	flaginac +	—		
(427) 134. Main tap at works - - - 6/12/05	flaginac +	fl +	—		
(428) 135. Main tap at works - - - 7/12/05	flaginac +	—			
(429) 136. Main tap at works - - - 8/12/05	flaginac +	—			
(430) 137. Main tap at works - - - 12/12/05	—				
(431) 138. Main tap at works - - - 13/12/05	—				
(432) 139. Main tap at works - - - 14/12/05	—				
(433) 140. Main tap at works - - - 15/12/05	flaginac +	—			
(434) 141. Main tap at works - - - 19/12/05	—				
(436) 142. Main tap at works - - - 20/12/05	—				
(437) 143. Main tap at works - - - 21/12/05	—				
(438) 144. Main tap at works - - - 22/12/05	—				

TABLE X.—*continued*

MAIN TAP WATER, RISING MAIN AT WORKS.

NUMBER OF B. COLI (OR COLI-LIKE MICROBES).

Description of the Sample.		Number of B. Coli (or coli-like microbes).				
		+ 100 c.c. of water.	+ 10 c.c. of water.	+ 1 c.c. of water.	+ ·1 c.c. of water.	+ ·01 c.c. of water.
(439) 145. Main tap at works - - -	27/12/05	—				
(440) 146. Main tap at works - - -	28/12/05	—				
(441) 147. Main tap at works - - -	29/12/05	—				
(442) 148. Main tap at works - - -	2/1/06	flaginac +	flaginac +	—		
(443) 149. Main tap at works - - -	3/1/06	flaginac +	—			
(444) 150. Main tap at works - - -	4/1/06	flaginac +	—			
(445) 151. Main tap at works - - -	5/1/06	—				
(446) 152. Main tap at works - - -	9/1/06	—				
(447) 153. Main tap at works - - -	10/1/06	flaginac +	—			
(448) 154. Main tap at works - - -	11/1/06	flaginac +	—			
(449) 155. Main tap at works - - -	12/1/06	—				
(450) 156. Main tap at works - - -	15/1/06	—				
(453) 157. Main tap at works - - -	16/1/06	—				
(454) 158. Main tap at works - - -	17/1/06	—				
(455) 159. Main tap at works - - -	18/1/06	—				
(456) 160. Main tap at works - - -	19/1/06	—				
(457) 161. Main tap at works - - -	23/1/06	—				
(458) 162. Main tap at works - - -	24/1/06	—				
(459) 163. Main tap at works - - -	25/1/06	—				
(460) 164. Main tap at works - - -	26/1/06	—				
(461) 165. Main tap at works - - -	30/1/06	—				
(462) 166. Main tap at works - - -	31/1/06	—				
(463) 167. Main tap at works - - -	1/2/06	—				
(464) 168. Main tap at works - - -	2/2/06	—				

TABLE X—*continued.*

MAIN TAP WATER, RISING MAIN AT WORKS.

NUMBER OF B. COLI (OR COLI-LIKE MICROBES).

Description of the Sample.	Number of B. Coli (or coli-like microbes). + 100 c.c. of water.	+ 10 c.c. of water.	+ 1 c.c. of water.	+ ·1 c.c. of water.	+ ·01 c.c. of water.
(466) 169. Main tap at works - - - 7/2/06	—				
(467) 170. Main tap at works - - - 8/2/06	—				
(468) 171. Main tap at works - - - 9/2/06	—				
(469) 172. Main tap at works - - - 13/2/06	—				
(470) 173. Main tap at works - - - 14/2/06	—				
(471) 174. Main tap at works - - - 15/2/06	—				
(472) 175. Main tap at works - - - 16/2/06	—				
(473) 176. Main tap at works - - - 20/2/06	—				
(474)177. Main tap at works - - - 21/2/06	—				
(475) 178. Main tap at works - - - 22/2/06	—				
(476) 179. Main tap at works - - - 23/2/06	—				
(477) 180. Main tap at works - - - 27/2/06	—				
(478) 181. Main tap at works - - - 28/2/06	—				
(479) 182. Main tap at works - - - 1/3/06	—				
(480) 183. Main tap at works - - - 2/3/06	—				
(481) 184. Main tap at works - - - 6/3/06	—				
(482) 185. Main tap at works - - - 8/3/06	—				
(483) 186. Main tap at works - - - 9/3/06	—				
(484) 187. Main tap at works - - - 13/3/06	—				
(485) 188. Main tap at works - - - 15/3/06	—				
(486) 189. Main tap at works - - - 16/3/06	—				
(488) 190. Main tap at works - - - 20/3/06	—				
(491) 191. Main tap at works - - - 23/3/06	—				
(493) 192. Main tap at works - - - 27/3/06	—				

TABLE X—*continued.*

MAIN TAP WATER, RISING MAIN AT WORKS.

NUMBER OF B. COLI (OR COLI-LIKE MICROBES).

Description of the Sample.	Number of B. Coli (or coli-like microbes).				
	+ 100 c.c. of water.	+ 10 c.c. of water.	+ 1 c.c. of water.	+ ·1 c.c. of water.	+ ·01 c.c. of water.
(496) 193. Main tap at works - - - 30/3/06	—				
(498) 194. Main tap at works - - - 3/4/06	—				
(A) 195. Main tap at works - - - - 5/4/06	—				
(501) 196. Main tap at works - - - 11/4/06	—				
(502) 197. Main tap at works - - - 18/4/06	—				
(503) 198. Main tap at works - - - 19/4/06	—				
(504) 199. Main tap at works - - - 20/4/06	—				
(506) 200. Main tap at works - - - 24/4/06	—				
(509) 201. Main tap at works - - - 27/4/06	—				
(511) 202. Main tap at works - - - 1/5/06	fl +	—			
(513) 203. Main tap at works - - - 4/5/06	—				
(515) 204. Main tap at works - - - 8/5/06	—				
(516) 205. Main tap at works - - - 16/5/06	—				
(517) 206. Main tap at works - - - 23/5/06	—				
(518) 207. Main tap at works - - - 30/5/06	—				
(519) 208. Main tap at works - - - 6/6/06	—				
(520) 209. Main tap at works - - - 14/6/06	—				
(521) 210. Main tap at works - - - 20/6/06	—				
(522) 211. Main tap at works - - - 27/6/06	—				
(523) 212. Main tap at works - - - 4/7/06	—				
(524) 213. Main tap at works - - - 11/7/06	O +	—			
(526) 214. Main tap at works - - - 18/7/06	—				
(527) 215. Main tap at works - - - 25/7/06	(fl) (ag) +	—			
(528) 216. Main tap at works - - - 27/7/06	—				

TABLE X—*continued.*

MAIN TAP WATER, RISING MAIN AT WORKS.

NUMBER OF B. COLI (OR COLI-LIKE MICROBES).

Description of the Sample.	Number of B. Coli (or coli-like microbes).				
	+ 100 c.c. of water.	+ 10 c.c. of water.	+ 1 c.c. of water.	+ ·1 c.c. of water.	+ ·01 c.c. of water.
(529) 217. Main tap at works - - - 31/7/06	(fl) +	—			
(530) 218. Main tap at works - - - 3/8/06	—				
(531) 219. Main tap at works - - - 7/8/06	—				
(532) 220. Main tap at works - - - 10/8/06	—				
(533) 221. Main tap at works - - - 14/8/06	—				
(534) 222. Main tap at works - - - 17/8/06	(fl) agac +	—			
(535) 223. Main tap at works - - - 22/8/06	(fl) ac +	(fl) ac +	—		
(536) 224. Main tap at works - - - 24/8/06	(fl) +	—			
(538) 225. Main tap at works - - - 28/9/06	flaginac +	fl (ag) inac +	—		
(539) 226. Main tap at works - - - 3/10/06	flaginac +	flaginac +	flaginac +	—	
(540) 227. Main tap at works - - - 5/10/06	flaginac +	—			
(541) 228. Main tap at works - - - 10/10/06	—				
(542) 229. Main tap at works - - - 12/10/06	—				
(543) 230. Main tap at works - - - 17/10/06	—				
(548) 231. Main tap at works - - - 19/10/06	flaginac +	flaginac +	—		
(553) 232. Main tap at works - - - 25/10/06	flaginac +	flaginac +	flaginac +	—	
(554) 233. Main tap at works - - - 26/10/06	flaginac +	flaginac +	flaginac +	flagac +	—
(555) 234. Main tap at works - - - 31/10/06	fl (ag) +	—			
(556) 235. Main tap at works - - - 2/11/06	—				
(557) 236. Main tap at works - - - 7/11/06	flaginac +	(fl) ag (ac) +	—		
(558) 237. Main tap at works - - - 8/11/06	flaginac +	flaginac +	flaginac +	—	
(559) 238. Main tap at works - - - 14/11/06	flaginac +	—			
(560) 239. Main tap at works - - - 16/11/06	(fl) +	—			
(561) 240. Main tap at works - - - 22/11/06	flaginac +	flaginac +	—		

TABLE X—*continued.*

MAIN TAP WATER, RISING MAIN AT WORKS.

NUMBER OF B. COLI (OR COLI-LIKE MICROBES).

Description of the Sample.		Number of B. Coli (or coli-like microbes).				
		+ 100 c.c. of water.	+ 10 c.c. of water.	+ 1 c.c. of water.	+ ·1 c.c. of water.	+ ·01 c.c. of water.
(562) 241. Main tap at works - - -	23/11/06	flaginac +	flaginac +	—		
(563) 242. Main tap at works - - -	28/11/06	—				
(564) 243. Main tap at works - - -	30/11/06	—				
(565) 244. Main tap at works - - -	5/12/06	(fl) (ag) +	—			
(567) 245. Main tap at works - - -	7/12/06	(fl) +	—			
(568) 246. Main tap at works - - -	12/12/06	fl +	—			
(569) 247. Main tap at works - - -	14/12/06	—				
(570) 248. Main tap at wroks - - -	19/12/06	flagac +	—			
(571) 249. Main tap at works - - -	21/12/06	flaginac +	—			
(572) 250. Main tap at works - - -	27/12/06	—				
(573) 251. Main tap at works - - -	31/12/06	—				
(574) 252. Main tap at works - - -	3/1/07	flaginac +	flaginac +	—		
(575) 253. Main tap at works - - -	7/1/07	flaginac +	—			
(576) 254. Main tap at works - - -	10/1/07	flaginac +	flaginac +	—		
(577) 255. Main tap at works - - -	14/1/07	flaginac +	—			
(578) 256. Main tap at works - - -	17/1/07	—				
(579) 257. Main tap at works - - -	21/1/07	—				
(580) 258. Main tap at works - - -	24/1/07	—				
(581) 259. Main tap at works - - -	28/1/07	—				
(582) 260. Main tap at works - - -	31/1/07	—				
(583) 261. Main tap at works - - -	4/2/07	—				
(584) 262. Main tap at works - - -	7/2/07	—				
(585) 263. Main tap at works - - -	11/2/07	—				
(586) 264. Main tap at works - - -	14/2/07	—				
(587) 265. Main tap at works - - -	18/2/07	flaginac +	(fl) +	—		
(588) 266. Main tap at works - - -	21/2/07	—				
(589) 267. Main tap at works - - -	25/2/07	—				
(590) 268. Main tap at works - - -	27/2/07	—				
(591) 269. Main tap at works - - -	28/2/07	—				

CHEMICAL ANALYSIS OF THE TREATED WATER. SAMPLES DRAWN FROM BOILER HOUSE TAP. PARTS PER 100,000.

Number of Sample.	Date when drawn. 1905.	Date when Analysed. 1905.	Ammoniacal Nitrogen.	Albuminoid Nitrogen.	Nitric Nitrogen. (1)	"Oxygen absorbed" from $\left(\frac{N}{80}\right)$ Permanganate in 4 hours at 27° C. (80° F).	Chlorine (present as Chloride).	Oxygen in Solution	Total Solids (dried at about 105° C).	Alkalinity (in parts $CaCO_3$ per 100,000) (2)	Reaction with Iodide and Starch Solutions.	Reaction with Iodide, Starch, and dilute Sulphuric Acid.	NOTES ON THE SAMPLES.
No. 3	Feb. 14th	Feb. 15th	0·002	0·014	0·260	0·128	4·02	1·20	42·7	13·90	None	Bright blue.	Clear, bright and colourless, with no suspended solids. Distinct chemist's shop smell. Alkaline.
No. 4	Feb. 15th	Feb. 16th	0·002	0·013	0·306	0·131	3·64	—	36·1	13·00	None	None.	Clear, with slight yellow tint. Perhaps a faint bleach smell? Alkaline.
No. 6	Feb. 20th	Feb. 22nd	0·004	0·016	0·272	0·142	4·10	1·26	40·6	12·25	None	Faint blue.	Clear and bright, with faint yellow tinge. No suspended matter. Faint mawkish smell, especially on warming. Alkaline.
No. 11	March 4th	March 6th	0·003	0·017	0·272	0·145	3·76	1·12	36·0	12·50	None	Faint blue.	Clear and bright. No suspended matter. Distinct but not strong, mawkish, spent bleach smell. Alkaline on boiling.
No. 14	March 13th	March 14th	0·006	0·016	0·228	0·178	3·70	0·97	35·0	10·60	None	Faint blue.	Clear and bright. No suspended matter. Slight mawkish (spent bleach) smell. Alkaline.
No. 17	March 20th	March 21st	0·006	0·019	0·286	0·206	3·30	—	37·0	10·50	—	None.	Fairly bright and clear, with brownish tinge. Practically no suspended matter. Mawkish smell. Alkaline.
No. 19	March 28th	March 29th	0·005	0·016	0·196	0·178	3·54	—	38·1	10·75	—	None.	Slightly brown, with trace of suspended matter. Mawkish smell.
No. 22	April 6th	April 7th	0·004	0·014	0·152	0·162	3·64	0·96	35·0	—	—	—	Bright and clear, with brownish tinge. No suspended matter. Mawkish smell. Alkaline.
No. 26	April 17th	April 18th	0·005	0·015	0·130	0·185	3·14	—	—	—	—	—	Clear and bright, with very slight brown tinge and minute quantity of whitish suspended matter. Mawkish smell. Alkaline.
No. 29	May 10th	May 11th	0·005	0·015	0·104	0·173	3·50	0·74	33·7	11·00	—	—	Clear & bright, with very slight brown tinge. Slight musty smell. Alkaline.
No. 30	May 27th	May 29th	0·003	0·018	0·069	0·177	3·88	0 67	37·0	9·65	—	—	Clear and bright, with no suspended matter. No smell. Alkaline.
No. 31	June 19th	June 20th	0·016	0·025	0·101	0·249	3·00	0·34	25·2	7·00	—	—	Distinctly yellow and not quite clear, with a small amount of red-brown suspended matter. Faint earthy smell. Neutral (alkaline on boiling.)
No. 32	June 26th	June 27th	0·002	0·018	0·030	0·191	3·92	0·44	35·3	—	—	None.	Clear and bright, with slight brown tinge, and a very small amount of brown suspended matter. Slight musty smell. Alkaline.
No. 33	July 4th	July 5th	0·005	0·019	?	0·220	—	—	—	—	—	None.	Slight brown tinge; a minute amount of suspended matter. Slight musty smell. Alkaline.
No. 35	Aug. 10th	Aug. 11th	0·015	0·021	0·102	0·231	5·46	0·46	—	—	—	None.	Clear and bright, with no visible suspended matter, but slightly brown in tint. Musty smell. Alkaline.
No. 36	Aug. 31st	Sept. 1st	0·003	0·016	0·090	0·152	4·56	—	35·3	—	None	Faintest possible reaction.	Clear, but slightly brown in tint. No suspended solids. Slight mawkish smell. Alkaline.
No. 37	Sept. 19th	Sept. 20th	0·005	0·018	0·055	0·137	—	0·61	40·6	10·0	—	—	Clear, but of a slight brownish tint. No suspended matter. Distinct mawkish smell. Alkaline.
No. 38	Sept. 26th	Sept. 27th	0·003	0·015	0·050	0·158	—	0·69	38·0	—	None	Very faint blue.	Clear and sparkling, with a very slight brownish tint. Exceedingly strong smell and taste of spent bleach.
No. 39	Sept. 28th	Sept. 29th	0·002	0·014	?	0·145	—	—	—	—	—	—	Clear and slightly brownish. Practically no smell or taste. Alkaline.
No. 40	Oct. 14th	Oct. 16th	0·002	0·014	0·226	0·147	—	—	—	—	None	None.	Clear and sparkling, with very slight brown tint; practically no smell. Alkaline.
No. 42	Oct. 21st	Oct. 23rd	0·002	0·015	0·206	0·139	4·52	—	—	—	—	—	Clear, but very slightly brownish. Slight mawkish smell and taste. Alkaline.
No. 44	Nov. 6th	Nov. 7th	0·003	0·013	0·210	0·145	3·95	0·81	44·0	—	—	—	Rather brownish and not very clear, with a considerable amount of very fine brown solids. A distinct (? lime) smell on warming. Alkaline.
No. 45	Nov. 30th	Dec. 1st	0·002	0·012	0.336	0·169	3·45	—	52·1	—	—	A trace of blue after 2 or 3 minutes.	Very slight brownish tint. Practically no smell or taste. Alkaline.
No. 46	Dec. 20th.	Dec. 22nd	0·002	0·009	0·436	0·122	—	—	—	—	—	None.	Bright and clear, with very slight brown tint. Hardly any taste or smell.
Sample of Ordinary Supply Water, drawn from filtered water tank, *before* the treatment with chloros began.													
No. 1	Feb. 10th 05	Feb. 13th 05	0·001	0·011	0·280	0·125	3·42	1·14	39·4	13·4	—	—	Clear, bright and colourless. No smell. Alkaline.
Samples of Unfiltered Water (No. 2 drawn from inflow pipe; No. 5 drawn (?))													
No. 2	Feb. 11th	Feb 13th	0·005	0·016	0·284	0·178	4·30	1·16	38·9	13·65	—	—	Rather turbid, with floating particles. Brownish tinge. No smell. Alkaline.
No. 5	Feb. 18th	Feb. 20th	0 003	0·016	0·300	0·175	—	...	41·3	14·25	—	—	Brownish, with a large amount of deposit. No smell. Alkaline.
No. 47	Jan. 15th/06	Jan. 16th/06	0·003	0·024	0·408	0·175	3·66	—	38·3	—	None	Pink at first, then a blue in one minute equal to about 1 in 100,000 of chloros, increasing to a deep blue.	Much more brown and opalescent than usual, with a distinct spent chloros smell and taste.

(1) None of the above samples showed any Nitrite in 50 c.c. of water.

(2) By neutralization with standard Sulphuric Acid, using Methyl orange as indicator.

APPENDIX C. I.—*continued.*

CHEMICAL ANALYSIS OF THE TREATED WATER. SAMPLES DRAWN FROM BOILER HOUSE TAP. PARTS PER 100,000.

Number of Sample.	Date when drawn.	Date when Analysed.	Ammoniacal Nitrogen.	Albuminoid Nitrogen.	Nitric Nitrogen. (1)	"Oxygen absorbed" from $\left(\frac{N}{80}\right)$ Permanganate in 4 hours at 27° C. (80° F.).	Chlorine (present as Chloride).	Oxygen in Solution	Total Solids (dried at about 105° C).	Alkalinity (in parts $CaCO_3$ per 100,000) (2)	Reaction with Iodide and Starch Solutions.	Reaction with Iodide, Starch, and dilute Sulphuric Acid.	NOTES ON THE SAMPLES.
	1905.	1905.											
No. 48	Jan. 24th	Jan. 26th	0·006	0·021	0·468	0·156	—	—	—	—	—	None.	Clear, but slightly brownish. Distinct mawkish taste and smell.
No. 49	Feb. 8th	Feb. 9th	0·010	0·018	0·588	0·107	2·75	—	47·5	—	—	None.	Much clearer than preceding sample, and with hardly any tint. Only a slight taste and smell.
No. 50	Feb. 22nd	Feb. 23rd	0·006	0·022	0·548	0·208	—	—	—	—	None	Blue equal to about 1 chloros in 100,000.	Rather brown and not very clear. Strong taste and smell of spent chloros.
No. 51	Mar. 10th	Mar. 12th	0·002	0·016	0·584	0·157	3·32	—	—	—	—	None.	Clear and not much tinted. Very little smell. Slight but distinct taste. Alkaline.
No. 53	April 2nd	April 3rd	0·002	0·013	0·416	0·113	3·08	—	—	—	None	Slight blue after 3 minutes.	Bright and clear, with little tint. Very slight smell and taste. Alkaline.
No. 58	May 21st	May 22nd	0·001	0·012	0·364	0·115	3·19	—	—	—	—	None.	Bright and clear. Distinct spent chloros smell. Alkaline.
No. 61	June 27th	June 29th	0·002	0·018	0·152	0·170	3·59	—	—	—	—	None.	Clear but with yellow-brown tint. Small amount of floating suspended matter. No smell or taste.
No. 63	July 26th	July 30th	0·001	0·015	0·024	0·186	3·74	—	—	—	—	—	Quite clear, with no suspended solids. Distinct brown tint. No smell and almost no taste.
No. 69	Sept. 5th	Sept. 6th	0·002	0·015	0·012	0·157	4·02	—	30·7	—	—	—	Clear and bright, with a very small amount of suspended solids. No smell.
No. 83	Nov. 12th	Nov. 13th	0·003	0·023	0·200	0·207	2·99	—	22·2	—	—	—	Very brown in tint.
No. 91	Dec. 19th	Dec. 20th	0·003	0·220	0·280	0·210	2·94	—	—	—	—	—	Clear, but brown in tint. No visible solids. No smell.
	1907.	1907.											
No. 97	Jan. 23rd	Jan. 25th	0·003	0·015	0·480	0·155	2·95	—	—	—	—	—	Clear and bright, with a trace of hair-like suspended solids. Slightly brown in tint. No smell.
No. 105	Mar. 26th	Mar. 27th	0·002	0·014	0·400	0·138	3·20	—	—	—	—	—	Clear and very bright, with slight brown tint. No taste or smell.
No. 106	May 2nd	May 3rd	0·002	0·013	0·380	0·109	3·30	—	—	—	—	—	Clear and bright but with a relatively large amount of exceedingly fine suspended solids. No smell.
No. 108	July 8th	July 9th	0·002	0·016	0·230	0·160	3·11	—	—	—	—	—	Clear, but rather brown in tint. No smell or taste.
No. 109	July 25th	July 26th	0·001	0·014	0·244	0·141	3·11	—	—	—	—	—	Rather brownish in tint. No smell or taste.
No. 110	Aug. 22nd	Aug. 23rd	0·002	0·013	0·246	0·115	3·49	—	—	—	—	—	Fairly clear, but with some very fine suspended solids. Slight brown tint. No smell.
No. 111	Sept. 24th	Sept. 25th	0·002	0·011	0·160	0·107	3·68	—	—	—	—	—	Clear, with a little fluff in suspension. Slightly brownish. No smell.
No. 113	Oct. 31st	Nov. 1st	0·002	0·017	0·266	0·171	3·10	—	—	—	—	—	Clear, but with a little fine yellowish solids in suspension. Slightly brown in tint. No taste or smell.
No. 114	Nov. 27th	Nov. 29th	0·002	0·020	0·124	0·229	2·81	—	—	—	—	—	Brownish and opalescent, due to a considerable amount of reddish-brown suspended matter, presumably oxide of iron. A small piece of hair in sample. No smell. Earthy taste.
No. 114	(After paper	filtration)	0·002	0·020	—	0·234	—	—	—	—	—	—	The paper filtered sample was still very brown tinted.
No. 115	Dec. 21st	Dec. 23rd	0·003	0·026	0·227	0·276	2·98	—	—	—	—	—	Distinctly brown in tint and slightly opalescent. An appreciable amount of fine light suspended matter. No smell or taste.
	1908.	1908.											
No. 116	Jan. 21st	Jan. 22nd	0·003	0·017	0·260	0·185	3·02	—	—	—	—	—	Clear, with no visible solids. Slight tint. Slight taste of spent chloros.
No. 118	Feb. 25th	Feb. 26th	0·002	0·014	0·216	0·159	3·15	—	—	—	—	—	Clear and sparkling, but slightly brown tinted. No smell. Distinct spent bleach taste.
No. 119	Mar. 30th	Mar. 31st	0·002	0·016	0·264	0·184	3·20	—	—	—	—	—	Bright and clear, but brown tinted. No suspended matter. No smell, but slight taste of spent chloros.
No. 123	April 30th	May 1st	0·001	0·012	0·196	0·157	3·14	—	—	—	—	—	Bright and clear with slight brown tint. No smell or taste.
No. 124	May 25th	May 26th	0·003	0·014	0·320	0·139	2·80	—	—	—	—	—	Clear, with brownish tint and a trace of brown suspended matter. No smell or taste.
No. 125	June 30th	July 1st	0·002	0·009	0·240	0·081	2·53	—	—	—	—	—	Clear, with very little tint. No smell and practically no taste.
No. 126	July 28th	July 29th	0·002	0·009	0·156	0·105	3·13	—	—	—	—	—	Clear, with brownish tint. No suspended solids. No taste, but a somewhat pungent earthy smell.
No. 127	Aug. 24th	Aug. 25th	0·002	0·007	0·256	0·077	3·27	—	—	—	—	—	Bright and clear, with hardly any tint. No taste or smell.

(1) None of the above samples showed any Nitrate in 50 c.c. of water. (2) By neutralization with standard Sulphuric Acid, using Methyl orange as indicator.

APPENDIX C. II.

TRENCH WATER.

ANALYSIS OF WATER FROM TRENCH BETWEEN FILTER BEDS Nos. 3 & 4 AND 5 & 6, NEAR THE LINE OF THE OLD DRAIN FROM THE URINAL ON THE WORKS.

	Sample No. 52.[1]	Sample No. 54.	Sample No. 59.
Drawn - -	March 27th or 28th, 1906.	April 10th, 1906.	May 21st, 1906.
Analysed - -	March 30th, 1906.	April 11th, 1906. (Filtered through paper before analysis.)	May 23rd, 1906.
Parts per 100,000.			
Ammoniacal Nitrogen -	0·95 [2] approx.	0·177.	0·098.
Albuminoid Nitrogen - -		0·052.	0·060.
Nitrous Nitrogen - -		0·0.	0·003 approx.
Nitric Nitrogen - - -	0·05.	0·265.	0·190.
"Oxygen absorbed" from permanganate in 4 hours at 27° C. - - -		0·70 (?).	1·067.
Chlorine (as chlorides) -	4·64.	3·43.	2·40.
Notes on sample when drawn	Where this water lay on the deposited concrete, a thick sediment had formed, having most brilliant colours—green, sea green, and yellow.		
Notes on sample when analysed - - -	The paper-filtered water was alkaline. It contained some lime and a little iron in solution. There was much mud at the bottom of the bottle. This was originally green, but became red on exposure to air. It dissolved for the most part in dilute acid, with effervescence. The insoluble portion consisted mostly of grit, together with some flocculent matter; the acid solution contained much iron (ferrous and ferric) and lime. There did not appear to be vegetable matter in the mud, under the microscope.	This sample was very turbid, from clayey matter. It filtered slowly through Swedish filter paper, almost clear, but very brown. Slowly alkaline. Earthy or lime smell upon warming. A portion evaporated to dryness left a residue which charred much on ignition, giving off a nitrogenous odour.	This sample was strongly alkaline, with a considerable amount of lime and sulphate in solution. Limy smell upon warming. June 11th—A distinct sediment had now deposited.

[1] Only a very small quantity of this was received, in a medicine bottle. [2] By direct Nesslerization.

APPENDIX C. III.

ANALYSIS OF A SAMPLE OF BLACK MUD FROM THE DRAIN PIPES AT BOTTOM OF No. 1 FILTER BED.

The following analysis is of interest, as showing the gradual accumulation of fine and partially unoxidized matter in the drain pipes of a sand filter.

Sample drawn, May 18th, 1905.
Sample analysed, May 22nd, 1905.
(It was probably kept in ice from May 20th to 22nd.)

	Per Cent.	
Moisture - - -	47·09	
Dry matter - -	52·91	3·19 Volatile on ignition. 49·72 Non-volatile.
	100.0	

Calculated on the *dry* matter, we get:—

	Per cent.
Volatile - - - - - - -	6·04
Non-Volatile - - - - - -	93·96
	100·0

Calculated on the *wet* mud:—

	Per cent. (*a*)	(*b*)
Total Nitrogen by Kjeldahl - - -	0·086	0·098
"Oxygen absorbed" from $\frac{N}{8}$ permanganate at 27° C. *at once* - - -	0·2	
"Oxygen absorbed" from $\frac{N}{8}$ Permanganate at 27° C. in three minutes -	0·44	
"Oxygen absorbed" from $\frac{N}{8}$ Permanganate at 27° C. in 4 hours - -	0·64	

The above sample consisted of mud, mixed with the ordinary sand of the filter bed. It had black streaks, evidently of ferrous sulphide, because sulphuretted hydrogen was given off on the addition of acid. The smell at first was inoffensive, but it became rather suspicious in a day or two.

APPENDIX C. IV.

A FEW LABORATORY EXPERIMENTS UPON THE AMOUNTS OF CHLOROS WHICH DIFFERENT WATERS WILL USE UP.

Various dilutions of chloros in four different waters were made, and the mixtures were allowed to stand in partly filled bottles. At the end of a specified time they were tested, as follows:—

February 20th, 1905. *Treated Water, Sample No. 4, taken.*

Time allowed for reaction, about 24 hours.

Dilution.	1 in 100,000	1 in 50,000	1 in 25,000	1 in 10,000
Subsequent addition of potassic iodide and starch solutions gave	No colour	Faint colour	—	
Iodide, starch, and dilute sulphuric acid gave	Faint colour	Appreciably darker colour	Very deep blue	—
Estimation of the hypochlorite remaining showed that the following amounts of the added chloros had been used up.	—	95 per cent.	About 80 per cent.	About 70 per cent.

February 28th, 1905. *Hartsholme Water, Sample No. 7.*

Time allowed for reaction, 18 hours.

Dilution.	1 in 100,000	1 in 50,000
Reaction with iodide, starch, and acid	No colour	No colour
Odour	Mawkish	Faint odour of spent chloros

February 28th, 1905. *Water from Catchwater Drain, Sample No. 8.*

Time allowed for reaction, 18 hours.

Dilution.	1 in 100,000	1 in 50,000
Reaction with iodide and starch	Distinct blue	—
With iodide, starch, and acid	—	Strong blue
Weak Thiosulphate (1 c.c. = ·0001135 grm. Cl) required to destroy the colour	One drop	0·1 c.c.
Odour	Faint chloros smell	Distinct chloros smell

March 3rd, 1905. *River Witham Water (Untreated), Sample No. 10.*

Time allowed for reaction, 24 hours.

Dilution.	1 in 100,000	1 in 50,000
Reaction with iodide and starch	—	Faint tinge
Reaction with iodide, starch, and acid	No colour	Just blue
Odour	No smell of chloros	Spent chloros smell

February 21st, 1905. *Raw unfiltered Water, Sample No. 5.*

Time allowed for reaction, 6 days.

	1 in 100,000	1 in 50,000	1 in 25,000	1 in 10,000
Reaction with iodide and starch	No colour	Very faint blue	Strong blue	—
Reaction with iodide, starch, and acid	No colour	Darker blue	—	—
Odour	Faint, mawkish	?	Distinct chloros smell	Strong chloros smell
Estimation of the hypochlorite remaining showed that the following amounts of added chloros had been used up.	—	—	93 per cent.	70 per cent.

The figures for albuminoid nitrogen and for "oxygen absorbed" in 4 hours, given by the above five samples, were :—

Parts per 100,000	No. 4	No. 7	No. 8	No. 10	No. 5
Albuminoid Nitrogen - - - - - - - -	0·013	0·035	0·020	0·019	0·016
"Oxygen absorbed" in 4 hours - - - - - -	0·131	0·284	0·194	0·158	0·175

The foregoing results are too few in number to allow deductions to be drawn, but they may perhaps be of some little use as regards future work.

APPENDIX C. V.

A FEW EXPERIMENTS ON THE EFFECT OF SUNSHINE UPON THE TREATMENT OF WATER WITH CHLOROS.

On p. 115 of this Report it is recommended that the treatment with chloros of water in open reservoirs, in warm bright weather, should be carried out after the sun has set. We found at Lincoln that the chloros in the treated water standing on the sand beds became exhausted much more rapidly in such weather than when the weather was dull and cool. The hypochlorite was evidently decomposed before it could exert its full bactericidal action, and hence a larger quantity of it had to be used.

The following preliminary laboratory experiments were therefore made, in order to test the influence of sunlight upon the rate at which chloros disappeared from water; the results are given in terms of c.c. of thiosulphate used for the titration of the residual hypochlorite.

Preliminary Experiments.

July 18*th*, 1905.—50 c.c. of a solution of 1 in 1,000 chloros in pure distilled water required 19·77 c.c. Thiosulphate.

A second 50 c.c. of a similar solution, exposed to sunlight for 3 hours (only about ½ hour's bright sunshine) - - - 0·80 c.c. Thiosulphate.

A third 50 c.c. of a similar solution, also set up for 3 hours, but protected during the whole time from the sunlight by black paper - - - 18·60 c.c. Thiosulphate.

July 19*th*, 1905.—A solution of 1 in 1,000 chloros in distilled water was again taken. In estimation (*a*), 50 c.c. of this were mixed with 50 c.c. of distilled water, while in estimations (*b*) to (*f*), 50 c.c. were mixed with 50 c.c. of Lincoln raw water; the thiosulphate required required by each dilution was then determined under the following conditions :—

	Length and conditions of contact of chloros and water.	Original Temperature.	Final Temperature.	C. C. Thiosulphate required.
(*a*) 1 in 2,000 chloros in glass distilled water - -	—	22·2° C.	—	21·28
(*b*) 1 in 2,000 chloros in equal volumes of distilled and of Lincoln raw water - - - - -	5 minutes - -	No doubt 22·2° C.	—	20·50
(*c*) Do. do. - -	½ hour in bright sunshine.	—	33° C.	5·37
(*d*) Do. do. - -	1 hour in bright sunshine.	—	37° C.	1·82
(*e*) Do. do. - -	1¾ to 2 hours in bright sunshine.	—	32·3° C.	0·35
(*f*) Do. do. - -	2 hours covered with black paper.	—	35·3 C.	17·58

In this second experiment the effect of exposure of the "chlorosed" water to sunshine was strikingly exemplified in the different results obtained under (*e*) and (*f*), where the conditions—apart from the bright exposure —were virtually identical. From bottle (*e*), which was placed in the sunlight, practically all the chloros had disappeared in two hours, while in bottle (*f*), which was protected by black paper, 80 per cent. of the hypochlorite remained.

We do not, however, assert that, under *actual* conditions of sterilization, other factors may not also play a part in the rapid decomposition of the chloros.

APPENDIX C. VI.

ACTION OF CHLOROS UPON SOIL DISTRIBUTED IN WATER.

The following simple experiments are of some interest, as bearing on the effect of chloros in water containing organic mud in suspension, though they are merely of a preliminary nature. A, Garden soil, and B, Fen soil, were employed.

February 22*nd*, 1905.—A. *Garden Soil.* 1.—A pinch of fine garden soil was added to 150 c.c. of 1 in 100,000 solution of chloros in Ealing tap water. After the mixture had stood for 2½ hours, the water itself had no smell, and it gave no reaction with iodide, starch, and acid, but the blue colour developed rapidly from the earth at the bottom of the flask.

B. *Fen Soil.* 2.—This gave the same result as the garden soil of experiment A, but the blue colour came back more rapidly on standing.

February 24*th*, 1905. 3 and 4.—Two similar experiments were made with a 1 in 10,000 chloros solution, about the same small quantities of soil being again used. The chloros in the water was exhausted in two days by both soils; the water of soil A had, however, in this case a slight mawkish smell, and that of soil B a strong one.

The above experiments thus illustrate :—

(1) The absorptive power of soil for chloros; and

(2) The action of the chloros (no doubt its joint solvent and oxidizing action) upon the organic matter present in soil.

APPENDIX C. VII.

EXAMINATION OF THE SAND OF FILTER BEDS WHICH HAD BEEN RECEIVING CHLOROS-TREATED WATER.

Samples of Sand from No. 6 Bed. Drawn February 21st, 1905.

	Percentage loss on ignition of the sand, dried at 110° C.
1. Unwashed sand from surface of bed	1·02 per cent.
2. Sand taken at a depth of 2 feet 6 inches	0·68 "
3. Washed sand from surface of bed	0·38 "

There was considerable charring in the case of No. 1, slight charring in No. 2, but no noticeable charring in No. 3.

Preliminary Experiment on Shaking up of Unwashed Sand with Water.

March 13th, 1905.—To-day an average sample of the top half-inch of sand from Bed No. 5 was drawn.

March 15th.—This gave :—

	Per cent.
Moisture	6·99
Matter volatile on ignition	0·96
Matter non-volatile	92·04
	100·0

March 16th, 1905.—11·29 grms. of this muddy sand were shaken up with *successive* quantities of distilled water (about 200 c.c. each time), the more or less muddy liquid siphoned off, and the "available chlorine" present in it determined in the usual way by the addition of potassic iodide, dilute sulphuric acid and starch, and titration with sodic thiosulphate. The results are given below, in terms of c.c. thiosulphate solution used :—

March 16th, 1905.	Muddy liquid settled.	Thiosulphate used.
11.30 a.m.	for ¾ hour	0·75 c.c.
12.0 a.m.	for ½ hour	0·12 "
1.30 p.m.	for 1½ hours	0·13 "
3.0 p.m.	for 1½ hours	0·04 c.c.
4.30 p.m.	for 1½ hours	0·02 "
March 17th, 1905 :—		
10.30 a.m.	for 18 hours	0·03 "

These preliminary results showed that the fine mud on the top of the sand had absorbed (? or combined with) an appreciable quantity of chloros, from which chlorine was liberated on the addition of dilute acid.

Subsequent Procedure.

For the examination of samples of sand like the foregoing, for absorbed chloros, the following procedure was therefore adopted.

20 Grms. of the muddy sand were shaken up with 200 c.c. distilled water, and the mixture was allowed to settle for five minutes. The supernatant muddy liquid was then treated as follows :—

50 c.c. were titrated with iodide, acid, and thiosulphate.

50 c.c. were titrated with iodide and thiosulphate.

50 c.c. were centrifugalised and the clear liquid was titrated.

This procedure was adopted because it was found that, if it was attempted to titrate the whole of the mixture of sand and water, with the addition of acid, etc., the back reaction (*i.e.*, liberation of iodine) went on almost at once.

The following results were obtained :—

Sample of Unwashed Top Sand from Bed No. 5. Drawn, March 13th, 1905.

Date of Estimation, March 21st, 1905.	Partially settled but muddy liquid.	Liquid after Centrifugalising.
A.—Titration with addition of acid	0·0075 per cent., available chlorine.	0·0018 per cent.,[1] available chlorine.
B.—Titration without acid	No reaction.	No reaction.
C.—Total Nitrogen (by Kjeldahl)	0·0198 per cent.	

These percentages are calculated on the wet sand (6·99 per cent. moisture), and the same applies to the percentage figures which follow.

Sample of Washed Sand from Bed No. 6. Drawn, March 16th, 1905.

Date of Estimation, March 21st, 1905.	Partially settled liquid.	Liquid after Centrifugalising.
A.—Titration with addition of acid	0·0018 per cent., available chlorine.	Slightest trace of available chlorine.[2]
B.—Titration without acid	No reaction.	No reaction.
C.—Total Nitrogen	0·0046 per cent.	

Samples of Sand from Bed No. 1. Drawn, May 3rd, 1905.

The water had been below the level of the sand since 9 p.m. on April 30th, but it had since been exposed to heavy rains :—

	No. 3. From top of bed.	No. 2. From middle, *i.e.*, at depth of 1 foot 3 inches.	No. 1. From bottom of bed, *i.e.*, at depth of 2 feet 6 inches.
May 11th, Volatile matter	1·63 per cent.	0·94 per cent.	1·25 per cent.
May 15th	1·51 "	0·92 "	1·17 "

[1] This liquid did not centrifugalise clear.

[2] This was a fairly clear but brownish liquid.

Samples of Sand from Bed No. 6. Drawn, December 8th, 1905.

Examined, December 9th, 1905.	Sample No. 1. "Skin."	No. 2. Surface sand.	No. 3. Sand at depth of 18 inches.
December 9th	0·0035* per cent., available chlorine.	0·0107 per cent.	0·0047 per cent.
December 18th	0·0 ,,	0·0090 ,,	0·0017 ,,
January 30th, 1906	0·0 ,,	0·0045 ,,	0·0009 ,,

The procedure here was the same as before, excepting that 100 c.c. in each case were titrated, with addition of acid. None of the samples had any smell of chloros when received:—

No. 1 was very dark in colour and had most mud.
No. 2 was dark brown, with rather less mud.
No. 3 was iron-brown, and had comparatively little mud.

Samples of Sand from Bed No. 4. Drawn, August 3rd, 1906.

Examined, August 4th, 1906.	No. 1. "Skin."	No. 2. Surface sand.	No. 3. Sand at depth of 18 inches.
Available chlorine	0·0028 per cent.*	0·0033 per cent.	0·0013 per cent.

* Blank = 0·0.

Sample No. 1 ("skin") was lumpy when received, and had to be ground up. When mixed with water it had a most pronounced sea-weed smell.

Samples of Sand from Bed No. 2. Drawn, May 31st, 1907, and sent in ice, some of which was still unmelted when the samples were received. The samples were kept in ice in the laboratory until they were done with.

The procedure was the same as before, excepting that 25 grms. of wet sand in each case were shaken up with 250 c.c. of distilled water, and three separate portions of 50 c.c. taken for examination. Five minutes' settlement was given, as before.

Examined, June 1st, 1907.	No. 1. "Skin."	No. 2. Surface sand.	No. 3. Sand at depth of 9 inches.	No. 4. Sand at depth of 18 inches.
Percentage of available chlorine.				
Partly settled muddy liquid	0·0104 per cent.	0·0146 per cent.	0·0076 per cent.	0·0035 per cent.
Centrifugalised liquid	0·001 ,,	0·0019 ,,	0·0010 ,,	Trace.

None of the muddy liquids gave any reaction when titrated *without* addition of acid.

Same Samples (of May 31st), kept in ice.

Procedure same as before, except that only half a minute, instead of five minutes, was given for settlement. Titration with addition of acid.

Examined, June 3rd, 1907.	No. 1.	No. 2.	No. 3.	No. 4.
Percentage of available chlorine.				
Muddy liquid	0·0124	0·0142	0·0055	0·0048
Centrifugalised liquid	0·0012	0·0025	0·0007	0·0003

The following deductions may, we think, be drawn from these experiments:—

The mud which is deposited mainly in the upper part of a sand water-filter absorbs (adsorbs, or combines with ?) a small but appreciable amount of hypochlorite from the "chlorosed" water. The mixture or compound, however, requires the addition of dilute acid before it can liberate iodine from potassic iodide; its hypochlorite or other chlorine compound is thus not in what may be termed the "active" state. This absorption is mainly or entirely due to the finely divided and flocculent clogging matter in the bed, and not to the sand itself.

The above admixture or compound of hypochlorite with mud does not decompose very rapidly on keeping, especially in cool weather: it persists to some extent for a number of days at atmospheric temperature. It is present in larger quantity in the surface sand than lower down in the bed, just as the surface sand contains more matter volatile on ignition. It is probably present in largest amount in the "skin," when a filter is in action, but after the skin and the surface sand are removed and allowed to dry more or less, the reducing action of the organic matter is no doubt more rapid in the skin than in the surface sand and lower down, since there must be relatively more organic mud in the former case.

Since this compound or mixture only liberates iodine from potassic iodide (within a short time, at all events), on the addition of acid, the presumption would be that its bactericidal properties were not very great. Some experiments actually carried out by us, to test the point, seemed to confirm this. At the same time, we are not in a position to offer a final opinion on the subject, which is one of much interest, and possibly also of practical importance as regards sterilization.

APPENDIX C. VIII.

"STRENGTH" OF VARIOUS CONSIGNMENTS OF CHLOROS.

The "strength" of chloros is conveniently stated in terms of percentage of "available chlorine," as determined by Bunsen's iodometric method. A little potassic iodide solution and dilute sulphuric acid are added to a given volume of aqueous chloros of known dilution, and the liberated iodine is titrated with $\frac{N}{10}$ thiosulphate, a few drops of clear starch solution being added towards the end of the titration.

5 c.c. of chloros is a convenient quantity to use. This is diluted to 100 c.c. with distilled water, 5 c.c. of the dilution and 10 c.c. of 1-in-10 sulphuric acid being taken for each titration.

The following table gives examples of the chloros, as used at Lincoln in 1905 and 1909.

	Available Chlorine.
February 11th, 1905	12·0 per cent.
February 23rd, 1905	12·8 ,,
February 23rd, 1905	11·6 ,,
November 7th, 1905	12·7 ,,
March 31st, 1909	12·1 ,,
May 10th, 1909	12·6 ,,
May 28th, 1909	13·5 ,,
July 2nd, 1909	13·8 ,,

Each of the above estimations represented a sample made up of sub-samples drawn from all the carboys of a consignment, or, at least, from a sufficient number of the carboys.

APPENDIX C. IX.

TESTING THE CHLOROS FOR TRACES OF ARSENIC.

As it was important to know that the chloros used for sterilization was free from arsenic, several consignments were tested for this. The method followed was that used by one of us in the work done for the Royal Commission on Arsenical Poisoning, and which is fully described in their Report, Vol. II., Appendices 22 and 23. A modification of Mr. Scudder's "Marsh" apparatus was employed.

The following results were obtained :—

Chloros :—	
Consignment 1	1 c.c. contained a trace of arsenic, say 0·00001 grm. As_4O_6.
Consignment 2	1 c.c. ,, ,, say 0·000013 ,, ,,
Consignment 3	1·05 c.c. ,, ,, say 0·00001 ,, ,,
Consignment 4	1 c.c. ,, ,, say 0·000005 ,, ,,
Mud which had collected at bottom of carboys of consignment No. 4.	1 c.c. contained a trace of arsenic, say 0·000018 grm. As_4O_6.

The quantity of arsenic which the water could receive from its treatment with chloros was thus infinitesimal.

With the object of comparing the treated and untreated waters, in regard to this, the following further determinations were made :—

250 c.c. of each of the waters in question were evaporated with a little lime water, the residue treated with aqueous sulphurous acid and again evaporated, and the final solution in hydrochloric acid "Marshed" in the usual way (*loc. cit.*).

No. 5. Raw Water. *No. 6. Treated Water.*	The result was in each case the same, *i.e.*, a *minute* arsenical mirror was obtained from each, this no doubt coming from the reagents used. Perhaps this mirror was a trifle heavier in the case of the raw water, say 0·0000013 grm., as against 0·000001 grm. from the treated water.

APPENDIX C. X.

ACTION OF WATER, WITH AND WITHOUT THE ADDITION OF CHLOROS, UPON LEAD PIPES.

Two sets of lead pipes were used in testing :—(1) Old encrusted pipes; and (2) new pipes which were only very slightly tarnished by the air. Each pipe was 2 feet long and ½ inch internal diameter, and it was closed by a cork at the lower end; the capacity was about 70 c.c. The water was allowed to stand in the pipe at atmospheric temperature for 24 hours, after which the lead in solution was determined colorimetrically as sulphide, a dilute standard solution of acetate of lead being used as the control.

The following Tables give the results obtained :—

February 18th, 1905. Water used—Sample No. 4; treated and sand-filtered water.

Old lead pipes.	Grms. of lead (Pb) taken up by 100,000 c.c. of water :— in 24 hours.*	in 2 or 3 days.
Water alone (*a*)	0·05	0·0
Water alone (*b*)	0·06	0·06
Water and chloros, 1 in 100,000	0·05	0·03
Water and chloros, 1 in 50,000	0·04	0·05
Water and chloros, 1 in 25,000	0·05	0·06
Water and chloros, 1 in 10,000	0·06	0·03

* Actually 23 hours.

The figures in the second column of the above table are only to be taken as approximate. After the 24-hour samples had been tested, the residual water (about 20 c.c. in each case) was allowed to stand in the pipe for one or two days longer, when it was again tested for lead.

February 21st, 1905. Water used—Sample No. 5, *i.e.*, raw, unfiltered Lincoln water :—

New lead pipes.	Grms. of lead (Pb) taken up by 100,000 c.c. of water in 24 hours.
Water alone (*a*)	0·08
Water alone (*b*)	0·10
Water and chloros, 1 in 100,000	0·09
Water and chloros, 1 in 50,000	0·08
Water and chloros, 1 in 25,000	0·08
Water and chloros, 1 in 10,000	0·07

February 22nd, 1905. Water used—Lincoln treated water No. 6, without any further addition of chloros :—

	Grms. of lead taken up by 100,000 c.c. in 24 hours.
(1) From old lead pipe	0·02
(2) From new lead pipe	0·08

The above experiments show that there is no danger to be feared from the sterilization of water by chloros, so far as regards the action of dilute solutions of chloros upon lead piping.

REPORT UPON THE "OXYCHLORIDE" EXPERIMENT AT GUILDFORD, BY MR. A. C. CARTER, F.I.C.

The "oxychloride" experiment at Guildford has consisted in the treatment of Guildford septic tank liquor upon two small percolating filters, 6 feet deep, the liquor flowing to one filter being mixed with a small quantity of an alkaline solution of sodium hypochlorite (called "oxychloride"), in order to deodorize it. The objects of the experiments were (1) to see whether the addition of the "oxychloride" did properly deodorize the septic tank liquor, and (2) to find out the effect of such addition with regard to the subsequent filtration of this liquor.

The observations were commenced on November 19th, 1906, upon filters which had been matured previously, and lasted till March, 1907. They consisted, chiefly, in noting the effects of the addition of different quantities of the "oxychloride" upon the septic tank liquor, the filter effluent, and the filter, the purification effected by this filter being compared with that obtained in the treatment of Guildford septic tank liquor alone, upon an exactly similar filter.

The Septic Tank Liquor.

The septic tank liquor used for the experiment was taken from the large septic tank (146,000 gallons capacity), which received at this time 70,000 gallons per day of 15 hours' flow, the tank resting during the night.

The liquor first flowed into a small cistern in which, by means of a ball cock attachment, the head of liquid was kept constant. From here it flowed into a second tank (in which a float was fixed for regulating the flow), where it was divided into two equal portions, by means of two V-notch weirs, each portion being subsequently discharged on to one of the two filters in periodical flushes from small syphon chambers. In one of the small syphon chambers the oxychloride was added to the septic liquor; one filter, therefore, received septic tank liquor which had been treated with the oxychloride, and the other filter received septic tank liquor alone. The Guildford septic tank liquor is very strong. It has a very foul smell, due mostly to sulphuretted hydrogen.

The Quantity of Septic Tank Liquor used.

The *rate* of filtration upon each filter throughout the experiment was approximately 51 gallons per cube yard per 24 hours. During the greater part of the observations, however, the filters worked for only 12 hours per day, each receiving 360 gallons of septic liquor during that time. This was equivalent to about 25 gallons per cube yard per 24 hours, although the *rate* of filtration during the 12 hours was about 50 gallons per cube yard per 24 hours.

The Filters.

The two percolating filters were exactly similar in every respect. They were each 6 feet deep and 9 feet in diameter, and had a capacity of 14 cube yards. The filtering material was coke, from one to three inches diameter, and the distribution was effected by means of revolving sprinklers, working intermittently.

The "Oxychloride" Solution.

The alkaline solution of sodium hypochlorite was obtained from the Oxychloride Company's Works at Forest Gate, London, E. As delivered at the works it contained about 13 per cent. of the hypochlorite, or about 12 per cent. of "available" chlorine.* As the quantities to be added to the tank liquor were very small, it was necessary to dilute it largely. For the first three experiments a solution yielding 0·1 per cent. of available chlorine was used, and for the last experiment one yielding 0·2 per cent. of available chlorine.

The diluted solution was kept in a covered barrel at the side of the small gauging tank. It was delivered into the septic tank liquor as the latter flowed over the small V-notch weir, complete admixture being obtained in this way. The flow from the barrel was kept constant by means of an ingenious constant head apparatus, designed by Mr. J. Fieldhouse, through which it passed before dropping into the septic tank liquor. Kept in the dark, the strength of the diluted "oxychloride" solution remained constant for at least a week; it was made up fresh once in every five or six days.

The Experiments.

Explanation of the term "25 per cent. Treatment."

The basis for the quantity of "oxychloride" to be added in the different experiments was the figure given for "oxygen absorbed" in five minutes at 27° C. from *weak*† permanganate (0·394 grm. $KMnO_4$ per litre) by the original tank liquor. This usually varied between 2·5 and 4 parts "oxygen absorbed" per 100,000, the average being about 3 parts. The figure 3·0 may therefore be taken for the purpose of this explanation. The above was suggested as a working basis by Oxychlorides, Limited.

What is meant by the term "25 °/。 treatment" with oxychloride is the addition, to 100,000 parts of tank liquor, of that quantity of oxychloride which yields, with acid, 25 °/。 of 3·0 or 0·75 part by weight of available chlorine. Since, however, it is alkaline hypochlorite and not free chlorine which is actually added, "25 °/。 treatment" means the addition to 100,000 parts of tank liquor of:—0·79 part pure sodium hypochlorite, equivalent to 0·17 part of (hypochlorite) oxygen, or 0·18 part of sulphuretted hydrogen. To put it differently, "25 °/。 treatment" requires 6·0 gallons *strong* oxychloride for 100,000 gallons of tank liquor; "35 °/。 treatment" 8·4 gallons; "50 °/。 treatment," 12·0 gallons; "100 °/。 treatment," 24·0 gallons. The above figures are on the basis of 3·0 parts "oxygen absorbed" in five minutes from "weak" permanganate by 100,000 parts of the tank liquor.

Experiment I.

The 25 per cent. Treatment. November 22nd to December 5th, 1906 (14 days).

During this experiment both filters worked at the *rate* of about 50 gallons per cube yard per day, for 12 hours each day. The effect of the treatment was the reduction of sulphuretted hydrogen in the treated septic tank liquor, a reduction amounting to about 4/5ths of the total quantity of sulphuretted hydrogen present. Although by no means entirely deodorized, the treated septic tank liquor was rendered much less offensive. It possessed a distinct spent bleach liquor smell, which helped to mask unpleasant odours. Standing on the leeward side of the filters, when both treated and untreated tank liquor were being delivered to them, the difference in the smell coming from the two sprinklers could be easily noticed.

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* The term "available chlorine" is used to indicate the chlorine which is set free when acid is added to a solution containing hypochlorite and chloride.

† The "oxygen absorbed" in 5 minutes from weak permanganate gives on the Guildford septic tank liquor a slightly higher figure than the "oxygen absorbed" *at once* from strong (*i.e.* $\frac{N}{8}$) permanganate (3·94 grm. $KMnO_4$ per litre). The proportions are approximately 1·2 and 1·0.

The following table gives the figures for "oxygen absorbed" from *strong* (*i.e.* $\frac{N}{8}$) permanganate,* for both the treated and untreated septic tank liquors. It shows a very slight reduction in the figures for the treated liquor, no doubt because of the oxidation of the sulphuretted hydrogen by the "oxychloride."

Septic Tank Liquors. Results in parts per 100,000, on average samples, each made up of 12 sub samples, drawn every hour for 12 hours.

Untreated liquor.				Treated liquor.		
Date.	No.	"Oxygen absorbed" at 27° C.		No.	"Oxygen absorbed" at 27° C.	
		At once.	In 4 hours.		At once.	In 4 hours.
November 23rd - - - - - -	24	4·06	12·17	25	3·99	12·08
„ 26th - - - - - -	41	3·91	10·83	42	3·91	10·64
„ 27th - - - - - -	45	4·36	12·03	46	4·21	11·89
„ 28th - - - - - -	49	3·97	11·13	50	3 88	10·84
„ 29th - - - - - -	53	3·13	9·60	54	3·10	9·60
Average of 5 Samples		3·88	11·15		3·82	11 01
December 4th - - - - -	67	2·14	8·41			
„ 5th - - - - - -	70	2·72	10·25			

With regard to the filter effluents from the two tank liquors, there was no difference in their appearance during this experiment, both being brownish coloured and opalescent, and containing small quantities of suspended matter.† The effluent from the filter receiving untreated septic tank liquor had a slight earthy smell, while the effluent from the filter receiving treated septic tank liquor possessed a slight spent bleach liquor odour. The following table gives the figures of analysis of the hourly samples of effluent corresponding to the samples of septic tank liquor of the same date :—

Filter Effluents (corresponding to the above Septic Tank Liquors).

Parts per 100,000.

Effluent from filter receiving untreated septic tank liquor.							Effluent from filter receiving treated septic tank liquor.					
Date.	No.	"Oxygen absorbed" at 27° C.		Nitrous Nitrogen.	Nitric Nitrogen.	Dissolved oxygen taken up from water in 24 hours at about 27° C.	No.	"Oxygen absorbed" at 27° C.		Nitrous Nitrogen.	Nitric Nitrogen.	Dissolved oxygen taken up from water in 24 hours at about 27° C.
		At once.	In 4 hours.					At once.	In 4 hours.			
Nov. 23rd -	26	0·98	2·78	0·10	1·41	—	27	1·05	2·76	0·10	1·33	—
„ 26th -	43	1·00	2·98	0·08	1·47	1·09	44	1·08	2·77	0·10	1·63	1·03
„ 27th -	47	0·87	2·56	0·10	2·25	0·87	48	0 90	2·56	0·13	2·35	0·77
„ 28th -	51	0.87	2·41	0·08	2·41	0·83	52	0·80	2·45	0·10	2·45	0·70
„ 29th -	55	0·69	2·05	0·12	2·46	—	56	0·72	2·02	0·14	2·38	—
Dec. 3rd -	65	—	—	0·13	1·83		66	—	—	0·10	1·92	—
„ 4th -	68	0·71	2·41	0·13	2·37	0·75	69	0·75	2·41	0·13	2·35	0·63
„ 5th -	71	0·85	2·82	0·10	2·38	1·13	72	0·80	2·85	0·10	2·74	0·93
Average - - -		0·87	2·56	0·11	2·07	0·89		0·87	2·55	0·11	2·15	0·81
Number of Estimations - -		(7)	(7)	(8)	(8)	(5)		(7)	(7)	(8)	(8)	(5)

It will be seen that nitrification was not in any way hindered as the result of the 25 per cent. treatment of the septic tank liquor with "oxychloride" solution.

Experiment II.

The 35 per cent. Treatment. December 6th to 10th, 1906 (5 days).

During this experiment both filters again worked at the *rate* of about 50 gallons per cube yard per day, for 12 hours each day. On December 6th the dose of "oxychloride" was increased from 25 per cent. to 35 per cent. Compared with the 25 per cent. experiment, the effect of this increase was very slight, as regards the smell of the tank liquor. In some cases the proportion of sulphuretted hydrogen in the treated and untreated septic tank liquors was reduced by as much as 7 to 1, but in none of the samples of treated liquor was sulphuretted hydrogen entirely eliminated.‡ As in the 25 per

* "Strong" permanganate was used in the analysis of all the samples of septic tank liquor and of filter effluent examined.

† All the filter effluents in this and the succeeding experiments were analysed as they came from the filters, *i.e.*, with their suspended solids included.

‡ This proportional figure was arrived at in the following manner :—

Two bottles, each of about 300 c.c. capacity, were filled, one with untreated and the other with treated septic tank liquor. To each bottle 5 c.c. of a saturated solution of aluminium sulphate and 1 c.c. of a 10 per cent. solution of caustic soda were added. Both bottles were then well shaken and allowed to settle for half an hour, after which 25 c.c. of the clear liquid were pipetted into Nessler glasses. 1 c.c. of strong acetic acid was then added to each Nessler glass, to render the liquid slightly acid, and finally 1 c.c. of a strong solution of lead acetate. The brownish colours thus obtained, due to lead sulphide, could then be compared with a fair degree of accuracy.

cent. treatment, the septic tank liquor receiving "oxychloride" still retained a slight "septic" smell, along with the accompanying spent bleach odour. The following are the figures of analysis for this experiment :—

Septic Tank Liquors, average samples. Parts per 100,000.

Untreated septic tank liquor.				Treated septic tank liquor.		
Date.	No.	"Oxygen absorbed" at 27° C.		No.	"Oxygen absorbed" at 27° C.	
		At once.	In 4 hours.		At once.	In 4 hours.
December 6th	73	2·60	9·39	74	2·47	9·39
" 7th	85	2·04	8·44	86	2·02	8·29
" 10th	89	2·46	10·08	90	2·42	10·02
Average of 3		2·36	9·30		2·30	9·23

Filter Effluents (corresponding to the above Septic Tank Liquors).
Parts per 100,000.

Effluent from filter receiving untreated septic tank liquor.							Effluent from filter receiving treated septic tank liquor.					
Date.	No.	"Oxygen absorbed" at 27° C.		Nitrous Nitrogen.	Nitric Nitrogen.	Dissolved oxygen taken up from water in 24 hours at about 27° C.	No.	"Oxygen absorbed" at 27° C		Nitrous Nitrogen.	Nitric Nitrogen.	Dissolved oxygen taken up from water in 24 hours. at about 27° C.
		At once.	In 4 hours.					At once.	In 4 hours.			
Dec. 6th	75	0·74	2·87	0·08	1·98	1·15	76	0·72	2·76	0·08	2·00	0·47
" 7th	87	0·78	2·69	0·06	1·98	—	88	0·77	2·69	0·06	1·96	—
" 10th	91	0·92	3·58	0·05	1·95	—	92	0·95	3·65	0·05	1·95	—
Average of 3		0·81	3·05	0·06	1·97	—		0·81	3·03	0·06	1·97	—

Here again the figures given by the two filter effluents are practically identical.

Experiment III.

The 50 per cent. Treatment. December 11th, 1906, to January 13th, 1907, with a break from December 21st to 31st (25 days).

During this experiment the filters again worked at the *rate* of about 50 gallons per cube yard per day, for 12 hours each day. The increased quantity of "oxychloride" completely destroyed all the sulphuretted hydrogen present in the septic tank liquor. The treated liquor possessed a slight fresh sewage smell, with an accompanying spent bleach liquor odour, and could not be called offensive.

Septic Tank Liquors, average samples. Parts per 100,000.

Untreated septic tank liquor.				Treated septic tank liquor.		
Date.	No.	"Oxygen absorbed" at 27° C.		No.	"Oxygen absorbed" at 27° C.	
		At once.	In 4 hours.		At once.	In 4 hours.
1906.						
December 11th	93	2·71	9·31	94	2·68	9·45
" 12th	97	2·97	9·66	98	2·64	9·70
" 13th	109	3·13	9·67	110	2·66	9·58
" 16th	113	2·36	9·26	114	2·36	8·98
" 17th	117	2·46	9·81	118	2·58	9·63
" 18th	121	3·10	9·28	122	2·63	9·33
" 19th	125	3·01	9·59	126	2·88	9·32
1907.						
January 1st	139	4·05	11·72	140	3·94	11·69
" 2nd	143	4·03	12·57	144	3·41	12·82
" 3rd	155	2·93	11·26	156	2·91	11·09
" 6th	159	2·71	10·79	160	2·66	10·73
" 7th	163	2·46	10·01	164	2·19	9·87
" 8th	167	3·10	11·66	168	2·94	11·54
" 9th	171	3·39	10·92	172	3·13	10·96
" 13th	183	2·74	8·84	184	2·69	8·79
Average of 15		3·01	10·29		2·75	10·23

It will be noted that the oxygen absorbed "at once" was now lower in the case of the treated septic tank liquor by 0·26 part. This was no doubt mainly due to the oxidation of sulphuretted hydrogen by the "oxychloride."

Free chlorine (*i.e.*, hypochlorite) was never found in the treated septic tank liquor going on to No. 2 filter.

Filter Effluents from the "50 per cent. Treatment." Average samples. Parts per 100,000.

Date.	Filter No. 1. Filter receiving untreated septic tank liquor. No.	"Oxygen absorbed" at 27° C. At once.	In 4 hours.	Nitrous Nitrogen.	Nitric Nitrogen.	Dissolved oxygen taken up from water in 24 hours at about 27° C.	Filter No. 2. Filter receiving treated septic tank liquor. No.	"Oxygen absorbed" at 27° C. At once.	In 4 hours.	Nitrous Nitrogen.	Nitric Nitrogen.	Dissolved Oxygen taken up from water in 24 hours at about 27° C.
Dec. 11th -	95	0·91	3·65	0·02	1·42	2·13	96	0·99	3·69	0·02	1·36	1·47
" 12th -	99	0·78	2·96	0·05	1·68	0·40	100	0·89	3·00	0·05	1·69	0·58
" 13th -	111	0·97	2·97	0·05	1·25	1·50	112	0·94	3·33	0·05	1·29	0·53
" 16th -	115	0·85	2·83	0·08	1·32	1·04	116	0·83	2·90	0·08	1·32	1·01
" 17th -	119	1·03	3·09	0·08	1·40	1·09	120	0·97	2·91	0·08	1·45	0·58
" 18th -	123	0·74	2·61	0·10	2·10	0·77	124	0·75	2·63	0·10	2·18	0·48
" 20th -	127	0·81	2·72	0·10	1·80	0·75	128	0·81	2·85	0·10	1·84	0·39
Jan. 1st -	141	0·80	3·08	0·05	2·49	0·71	142	0·74	2·97	0·04	2·46	0·80
" 2nd -	145	0·89	2·64	0·06	2·76	0·56	146	0·75	2·66	0·06	2·92	0·54
" 3rd -	157	0·74	2·96	0·05	2·13	—	158	0·78	2·89	0·05	2·37	—
" 6th -	161	0·88	2·66	0·08	2·50	—	162	0·78	2·49	0·08	2·60	—
" 7th -	165	0·50	2·31	0·06	2·48	0·40	168	0·55	2·11	0·06	2·54	0·74
" 8th -	169	0·77	2·46	0·10	2·52	0·07	170	0·77	2·34	0·08	2·84	0·50
" 9th -	173	0·69	2·41	0·02	2·78	—	174	0·69	2·15	0·01	2·92	—
" 13th -	185	0·61	1·88	0·17	3·36	0·46	186	0·58	1·72	0·20	3·63	0·42
Average of 15	-	0·80	2·75	0·08	2·13	0·82*		0·79	2·71	0·07	2·23	0·67*

* Average of 12 samples.

It will be seen from this table that, on the average, the two effluents were again practically identical, chemically. Samples Nos. 162 to 186 showed a slight increase in nitric nitrogen as compared with Nos. 161 to 185, but this was probably due to the fact that No. 1 filter was at the time treating rather more (7 per cent. more) septic tank liquor than No. 2 filter; in any case the differences were very small. The conclusion to be drawn, therefore, is that the "50 per cent. treatment" by oxychloride rendered the foul septic tank liquor inoffensive as regards smell, without affecting the quality of the filter effluents from a chemical point of view.

Growths on Filters.

A grey growth made its appearance on both filters during the 25 per cent. and 35 per cent. experiments. During the 50 per cent. experiment there were some indications that it was flourishing rather better on the filter receiving the ordinary septic tank liquor than on that receiving the treated septic tank liquor, the coke on the surface of the latter being cleaner in appearance and having more green growth upon it.

General Conclusions on the 25 per cent., 35 per cent., and 50 per cent. Treatments.

So far as can be judged from the foregoing experiments, the "25 per cent., 35 per cent., or 50 per cent. treatment" of the Guildford septic tank liquor with "oxychloride" does not affect its subsequent purification upon percolating filters. The 25 per cent. and 35 per cent. treatments very greatly reduced the amount of sulphuretted hydrogen in the liquor and consequently made it much less liable to give rise to nuisance. The 50 per cent. treatment rendered the liquor practically inoffensive as regards smell and reduced the liability to nuisance to a minimum.

In conclusion, I should like to add that I have been very much indebted to Mr. J. Fieldhouse, the manager at Guildford for the "Oxychloride" Company, for the great help which he has given me throughout these observations.

February, 1907. A. C. Carter.

Addendum.

Although the foregoing observations showed that the "50 per cent. treatment" would probably suffice for all practical purposes, when dealing with the Guildford septic tank liquor, it was thought advisable to ascertain how *strong* a dose of "oxychloride" could be added to the septic liquor without interfering with the proper working of the filter on which it was to be subsequently treated.

With this object in view, Mr. J. Fieldhouse conducted a further series of experiments under our instructions, after the direct observations for the Commission had been completed.

These experiments consisted in the "100 per cent., 200 per cent., 500 per cent., and 1,000 per cent. treatment" of the septic tank liquor with "oxychloride," noting the effect on the effluent obtained, especially with respect to nitrification.

The filters were again worked at the *rate* of about 50 gallons per cube yard per day, for 12 hours each day, throughout these experiments.

The "100 per cent. Treatment." Feb. 18th to May 13th, 1907.

With this dose of "oxychloride," an excess, amounting to about 1·0 part of available chlorine per 100,000, persisted in the treated septic tank liquor, the smell of which was masked by the spent bleach odour.

The filter effluents from the two tank liquors were similar in appearance.

The respective average figures for nitric nitrogen in 66 samples, together with the minimum and maximum figures, in each case, were:—

Parts per 100,000.

Effluent from filter receiving untreated septic tank liquor.		Effluent from filter receiving treated septic tank liquor.	
(0·60–5·82)	2·38	(0·21–5·81)	2·59

The "200 per cent. Treatment." May 14th to May 30th, 1907.

The septic tank liquor was considerably bleached by this dose, but the effluents were indentical in appearance.

The respective average figures for nitric nitrogen in 13 samples, in each case, were:—

Parts per 100,000.

Effluent from filter receiving untreated septic tank liquor.		Effluent from filter receiving treated septic tank liquor.	
(4·10–6·21)	4·84	(4·10–6·46)	4·92

It will be seen, therefore, that nitrification was not hindered, as the result of the "100 per cent. and 200 per cent. treatment" of the septic tank liquor with "oxychloride" solution.

The 500 % Treatment. May 31st to June 10th, 1907.

This dose bleached the tank liquor to a pale yellowish colour. The excess of "oxychloride" in the treated liquor going on to the filter amounted to 12–16 parts of available chlorine per 100,000.

The effluent from the filter receiving the treated tank liquor was affected considerably by this dose, both as regards its appearance and the amount of nitric nitrogen which it contained.

The respective average figures for nitric nitrogen in 10 samples, in each case, were :—

Parts per 100,000.	
Effluent from filter receiving untreated septic tank liquor.	Effluent from filter receiving treated septic tank liquor.
(4·62—5·98) 5·26	(2·90—5·05) 4·00

The 1000 % Treatment. June 11th to July 12th, 1907.

The treated tank liquor was completely bleached by this large dose, and it contained an excess of "oxychloride" equivalent to about 30 parts of available chlorine per 100,000.

The quality of the effluent obtained from the filter receiving the treated tank liquor was immediately affected, the nitric nitrogen being reduced by nearly 50 per cent., as compared with the effluent obtained from the filter receiving the untreated tank liquor.

After a fortnight had elapsed, nitric nitrogen had disappeared from the first-named filter effluent altogether ; it was then very thick and turbid in appearance, and contained a considerable amount of "oxychloride."

To sum up briefly, these supplementary experiments, carried out by Mr. Fieldhouse, showed that the "100 per cent. and 200 per cent. treatment" did not affect the working of the filter, but that the "500 per cent. treatment" did affect the working to a considerable extent, while with the "1000 per cent. treatment" nitrification soon ceased.

The earlier experiments showed that the "50 per cent. treatment" of the Guildford septic tank liquor was more than sufficient to get rid of all the sulphuretted hydrogen present, and these later experiments prove that there is a wide margin of safety, as regards the efficient working of the filters, in the event of the tank liquor accidentally receiving too large a dose of "oxychloride."

May, 1909. A. C. Carter.

BRIEF NOTE BY Dr. HOUSTON ON SOME OF THE BACTERIOLOGICAL ASPECTS OF THE INVESTIGATION.

The 25, 35 and 50 per cent. "treatments" had no very marked effect bacteriologically, either on the "treated" septic liquor going on to filter No. 2, or on the effluent from that filter.

But the 100 per cent. treatment reduced, to a striking extent, the total number of bacteria and the number of B. coli, both in the "treated" septic liquor and in the effluent from filter No. 2. The results yielded by the tests for B. enteritidis sporogenes and nitroso-bacteria, however, remained relatively unaffected.

When the dose was increased to 200 per cent., all the B. coli were killed in the treated septic liquor, and there were practically none found in the effluent. As regards the total number of bacteria, it was noted that although the treatment destroyed nearly all the microbes in the septic liquor, a considerable number of bacteria were still present in the effluent. Similarly, the 200 per cent. treatment destroyed the nitroso-bacteria in the septic liquor and yet a large number of these microbes could still be found in the effluent.

The 1,000 per cent. treatment killed practically all the bacteria in the septic liquor, and even the B. enteritidis sporogenes test yielded negative results ; nevertheless, the effluent, although it contained no B. coli, was still found to contain bacteria of other sorts.

The bacteriological results, read in conjunction with the chemical results, suggest the following conclusions :—

1. That a *mature* filter can continue its work of purification, independently of the presence of fresh living bacteria in the liquid undergoing treatment.

2. That B. coli (and by inference the typhoid bacillus) can be killed in a sewage liquid, antecedently to its application to a *mature* filter, without imperilling *necessarily* the bacterial activity and purifying ability of such a filter.

3. That when the B. coli and nitrifying bacteria are killed in the liquid about to be purified on a *mature* filter, the effluent therefrom may cease to yield any B. coli and yet contain many nitrifying bacteria, the reason apparently being that B. coli is merely a "passenger," whereas the nitrifying germs are "at home" in a *mature* filter ; and *unless* the germicidal agent is present in so great an excess as to be operative throughout the entire depth of the filter, they may still continue to multiply and exercise their oxidising functions.

4. That the evidence is against the possibility of a filter acting as a sort of breeding ground for any pathogenic bacteria, which may have been accidentally introduced into the filter through the medium of the onflowing sewage. For, it is to be noted that at the point where B. coli was killed in the septic liquor, but where the dose was insufficient to paralyse the filter itself, B. coli practically disappeared from the effluent, although the effluent still contained an abundance of other bacteria.

A. C. Houston.

October, 1909.

REPORT ON THE EXPERIMENTAL WORK CARRIED OUT AT DORKING DURING THE YEARS 1905 TO 1909 BY MR. ERIC H. RICHARDS, B.Sc.

PREFATORY NOTE.

The experiments described in this report have been carried out for the Commission at the Outfall Works of the Dorking Urban District Council, who have been so kind as to afford every facility for them. The Council not only supplied the site for the experimental plant, but also lent an excellent room for laboratory purposes.

It should be stated at the outset that the whole of the work at Dorking was the subject of special preliminary consideration by the Commission. Several meetings were largely devoted to a discussion of the proposed experiments and two visits were subsequently paid to Dorking while the experiments were in progress. I should also like to refer here to the material help given by Mr. F. J. Willis, Secretary to the Commission, throughout the work.

In accordance with the instructions of the Commission, each experiment was carefully planned by the senior members of the staff, acting along with myself. The experimental plant was designed by Mr. G. B. Kershaw, with the specific object of allowing the various processes to be readily and accurately compared; this has contributed largely to the success of the experiments. The conduct of the experiments was entrusted to myself, acting under the guidance of Dr. McGowan and Mr. C. C. Frye, who have also advised in the interpretation of the results as set out in this report. The experiments on the sterilisation of filter effluents were done under Dr. Houston's direction.

Most of the analyses have been made in the laboratory at the Dorking works, but the majority of the samples drawn in the Limed Septic Liquor experiment and some of those in the Deep and Shallow Filter experiment were analysed in Dr. McGowan's laboratory at Ealing by Mr. A. C. Carter, Mr. A. F. Girvan and Mr. W. G. Winterson. Dr. McGowan also arranged for Mr. Carter or Mr. Girvan to assist me occasionally in the work at Dorking; the "Time of Contact" experiments, which alone entailed over 3,000 estimations of chlorine, could hardly have been carried out without their help, for which I owe them my hearty thanks. Mr. Girvan also suggested several improvements in the practical details of the installation.

I must further express my indebtedness to Mr. G. Somers Matthews, Surveyor to the Dorking Council, and to Mr. C. Webb, Works foreman, for their kind assistance throughout the experiments. Lastly, I should like to place on record the services of Mr. J. Taylor, who has been employed by the Commission and who has assisted me during the whole course of the experiments, mainly in connection with the outdoor work. The collection of the samples, among other things, rested mainly with him; and when it is stated that something like 12,000 samples were drawn, by day and night and in all weathers, the arduous nature of his duties will be readily understood. All his work was thoroughly and carefully done. Further, Mr. Taylor successfully carried out several structural alterations in the plant.

E. H. R.

NOTE ON METHODS OF ANALYSIS.

The analyses given in this report have been made by the methods described in the Fourth Report of the Commission, Vol. IV., Part V. Attention may, however, be called to the following points :—

(1) Ammonia-free water, distilled from water slightly acidified with sulphuric acid, was used in all the estimations of ammoniacal and albuminoid nitrogen.

(2) The term "Total Nitrogen" means nitrogen as determined separately by the Kjeldahl method.

(3) The permanganate employed in the "oxygen-absorbed" tests was the "strong," *i.e.* ($\frac{N}{8}$) solution (3·94 grammes $KMnO_4$ per litre).

(4) The "oxygen absorbed in 3 *minutes*" test was substituted for the "*at once*" test in the analyses given in Part. III.

(5) The determinations of dissolved oxygen were done by Winkler's (manganese) method, as modified by Rideal and Stewart.

(6) All the percentage purifications are calculated on the *atmospheric* oxygen taken up, unless otherwise stated.

PART I.—EXPERIMENTS ON THREE METHODS OF TANK TREATMENT.

OBJECTS OF THE EXPERIMENTS.

The objects of the experiments were :—

(1) To compare the working of three processes in general use for the reduction of suspended matter present in sewage, viz. :—

(*a*) Simple settlement with continuous flow ;
(*b*) Precipitation with continuous flow ;
(*c*) Open septic tank.

(2) To compare the effluents resulting from the filtration of the above three tank liquors through percolating filters of coarse material.

(3) To observe the effect of settlement followed by sand-filtration upon the filter effluents, with regard primarily to the removal of micro-organisms and secondarily to further improvement chemically.

(4) To experiment upon the sterilization of the filter effluent.

DORKING SEWAGE.

The flow of sewage to the Dorking works in dry weather is about 200,000 gallons per day.

The town is sewered on the partially separate system. A considerable amount of storm-water thus reaches the works in wet weather, the maximum quantity amounting to between two and three times the dry weather flow.

A certain amount of subsoil water gains access to the sewers, probably about one-quarter to one-fifth of the dry weather flow.

The sewage is essentially a domestic one ; only a small amount of slaughter-house refuse and the waste from one small brewery come down at long intervals.

The strength of the sewage varies greatly throughout the week, especially as regards suspended matter. On Monday and Tuesday it is very strong, with much suspended matter. During the remainder of the week it remains of moderate strength, the minimum being reached on Sunday, at night.

The sewage, as used in the experiments about to be described, was sampled by twenty-four hours' average samples, drawn hourly and mixed in equal fractions for each hour, *i.e.*, according to the rate of flow to the experimental tanks. Twenty-one sets of hourly samples, in all, were taken in this way at intervals of fifteen days. Three samples were thus drawn, for each day of the week, and the figures obtained by their analysis show remarkable regularity for the whole period, allowance being of course made for the effect of rain on certain of the samples.

It should be noted that while these average hourly samples represent the strength of the sewage as flowing over the intake to the experimental tanks, the true average figures for the Dorking sewage are considerably higher, as the amount of clear subsoil water which comes down to the works from midnight to 6 a.m. causes the hourly samples to be proportionally diluted.

This dilution of the strong day sewage with the weak night sewage, to a greater extent than occurs with the whole Dorking flow, had considerable effect on the results obtained during the year's experiments. Firstly, it gave a lower average strength to the sewage, and caused great fluctuations in the strength of the tank liquors going on to the filters ; this is not a state of things favourable to a high percentage purification. Secondly, the continuous flow of sewage during the night, at a rate equal to that for the strongest day sewage, gave no opportunity for better settlement, as is normally the case in actual practice, when the small flow of night sewage allows the day sewage, already in the tanks, a much slower rate of flow, with better chance of settlement.

The following Table gives the figures of analysis for the hourly sewage samples examined :—

FIGURES FOR SCREENED SEWAGE.—21 SETS OF HOURLY SAMPLES.

Parts per 100,000		Average.	No. of Estimations.
Ammoniacal Nitrogen	(2·63 to 5·69)	4·65	(21)
Albuminoid Nitrogen	(0·56 to 1·66)	1·00	(20)
Total Organic Nitrogen	(1·17 to 3·11)	1·92	(20)
Oxidized Nitrogen	(0·00 to 0·76)	0·11	(21)
Total Nitrogen (by Kjeldahl)	(4·51 to 8·58)	6·72	(20)
"Oxygen absorbed" at 27° C. *at once*	(1·20 to 3·41)	2·38	(21)
" " " *in 4 hours*	(6·37 to 14·77)	10·01	(21)
Chlorine	(5·58 to 16·64)	8·71	(20)
Solids in suspension	(11·7 to 32·8)	21·50	(21)

SUPPLY OF SEWAGE.

The supply of sewage to the experimental installation was taken from the channel leading from the main outfall to the tanks at the works of the Dorking Urban District Council. The sewage passes through a small grit chamber and a 1-inch screen before reaching this channel. Immediately behind this screen a floating weir delivered a constant flow of 15,000 gallons per twenty-four hours to the tanks of the installation. Before reaching the latter, the flow was subdivided into three equal flows of 5,000 gallons each, per twenty-four hours, and these were led by open channels to the tanks.

TANKS.

There are four rectangular tanks, constructed of concrete with cemented surface. Three of these are similar in all respects, each having a capacity of 2,087 gallons. One tank was used for "Simple settlement" and one for "Precipitation," while the third was used for either process when one of the other two was being emptied for sludging.

The fourth tank is similarly proportioned to the other three, but is rather more than twice their size, having a capacity of 5,500 gallons. This tank was used as an "Open septic tank." All the tanks are fitted with sludge valves and floating arms. The sludge pipes drain to a well, from which the sludge is pumped by a chain-pump for measurement and sampling.

METHODS OF TANK TREATMENT.

(1) *Simple Settlement with Continuous Flow.*

The screened sewage flowed into the settling tank over a sill extending the full width of the tank, and flowed out over a similar sill at the opposite end.

A uniform flow of 5,000 galllons per twenty-four hours was maintained throughout the experiment. This was sufficient to fill the tank in ten hours.

Sludging.—From November 15th, 1905, when the experiment commenced, until the middle of June, 1906, the tank was emptied and cleaned once in each week. Before doing this, the spare tank was filled with sewage, so that a continuous supply of settled sewage was always delivered to the filter. During the hot summer weather, which lasted to the end of September, 1906, the tank was emptied once every four days. If allowed to run beyond this time, the sludge fermented and rose to the surface in large masses. The supernatant liquor was run off through the floating arm on to a plot of ground at a lower level. Owing to the shape of the tank bottom and the small amount of sludge (usually about 1 cube yard) which was removed each time, it was not possible to run off as much of the supernatant liquor as could be done on a large scale. The sludge consequently contained a higher percentage of water than that produced in bulk, by this method of settlement.

The pumping of the sludge from the well to the measuring box gave rise to some smell in the warm weather, but there was never any serious nuisance. The sludge was, at first, run into small bays and allowed to dry naturally, but as this took a very long time in the wet weather of the winter and early spring, the method was abandoned in May, 1906, when the warm weather caused the accumulation of half-dried sludge to become objectionable. From this time the sludge was run into the manhole of the Dorking Works, and pressed in the usual way with the bulk of sludge from the works.

The quantity of wet sludge removed from the settled sewage tank during the experiment amounted to 60·50 cubic yards or 46·20 tons. This contained an average of 4·26 per cent. of dry solid matter; hence the actual dry solids from 1,843,000 gallons of sewage amounted to 1·97 tons.

(2) *Precipitation with Continuous Flow.*

The sewage was run into the precipitation tank in exactly the same way as described for "Simple settlement," *i.e.*, at the rate of 5,000 gallons per twenty-four hours, or ten hours' settlement. Just before reaching the tank the sewage flowed through a small baffle-box, to ensure the thorough mixture of the precipitant, which was added at this point.

The precipitant used throughout the experiment was "alumino-ferric"—first alone and afterwards in conjunction with lime.

The solid precipitant was weighed out as required and dissolved in tap water in a 40-gallon cask. The solution, after settlement to remove a small amount of grit, was run into another 40-gallon cask, from which a fine jet delivered it at the proper rate to the baffle-box beneath.

For the first three weeks the alumino-ferric was added at the constant rate of 10 grains to each gallon of sewage. This did not give a satisfactory precipitation with the strong day sewage and was too large a quantity for the weak night sewage. The rate was then varied according to the strength of the sewage, 15 grains per gallon being added during the day and 5 grains at night, the average quantity being the same as before, *i.e.*, 10 grains per gallon. This method of working was continued for twelve weeks, but the suspended matter in the precipitation liquor still amounted to an average of 7·7 parts per 100,000. The addition of lime during the day, along with the "alumino-ferric," was then tried, and this gave distinctly better results at once. For the remainder of the year, therefore, the precipitants used were 10 grains of alumino-ferric and 5 grains of lime per gallon of sewage per twenty-four hours. The lime was added as milk of lime, and only from 8 a.m. to 5 p.m. each day.

Sludging.—The precipitation tank was emptied at exactly similar intervals to the settled sewage tank and the process was the same in both cases. The precipitation tank would always run slightly longer than the other, before fermentation brought the sludge to the surface. As, however, the only spare tank had to serve for both processes in turn, it was necessary to empty the sludge from each process alternately.

The removal of the precipitation sludge never gave rise to more than local nuisance. Its smell was always less objectionable than that from the settled sewage tank. These remarks apply to fresh sludge removed from the tanks at the proper time, before fermentation had become active.

The precipitation sludge was always less dense than that from simple settlement, with a correspondingly larger proportion of water.

The wet sludge produced by this process amounted to 99·59 cubic yards, or 75·70 tons. This contained an average of 3·18 per cent. of dry solid matter; hence, the actual dry solid from 1,843,000 gallons of sewage was 2·41 tons.

(3) *Open Septic Tank.*

The septic tank, which is similarly proportioned to the smaller tanks, has a capacity of 5,500 gallons, and a flow of 5,000 gallons per twenty-four hours was maintained throughout the experiment.

The tank was first filled on November 15th, 1905, and ran for 338 days to November 15th, 1906. From December 21st to January 15th, 1906, all the tanks were stopped while some alterations were being made to the scum-boards, but all sludge taken from the septic tank was replaced. There was no loss of sludge.

As the tank began to work in the late autumn, "septic" conditions were a long time in making their appearance. Not until March 3rd, 1906, did scum appear in any quantity, when the whole surface became rapidly covered with a layer about 2 inches thick, through which considerable quantities of gas were discharged. This stayed for a short time, but on March 7th had all disappeared. During these periods of activity the liquor had a typical septic smell, but between them only a stale sewage smell. On June 1st, a permanent scum had formed, and this increased in thickness till the tank was emptied on

November 15th, 1906, when it averaged about 6 inches. During this latter period the liquor was highly septic, with a strong sulphuretted hydrogen reaction. The suspended solids leaving the tank kept very constant at about 8 parts per 100,000 until the end of May, when flushes of solid up to 20 parts per 100,000 were discharged from the tank. The weather at this time was exceedingly hot, frequently 85–90° F. in the shade. The rising of masses of sludge between the scumboard and the outlet sill of the tank was the cause of considerable increase in the solids leaving the tank during its periods of activity. On March 13th an iron plate was fixed below the scumboard, being sloped downwards at an angle of 45° towards the end wall of the tank. This kept back a large amount of sludge, which would otherwise have gone on to the filter.

When the tank was emptied, November 15th to November 21st, 1905, 17·59 cubic yards of sludge and scum were removed. This weighed 13·65 tons and contained 6·37 per cent. of dry solid; hence the actual dry solids from 1,690,000 gallons* of sewage amounted to 0·87 ton. The sludge had a strong smell, but gave rise to no great nuisance in the pumping and measuring operations. It was much darker than the other sludges, but by no means black.

As a precautionary measure, 14 lbs. of bleaching powder were added to the sludge after sampling. One ton of dry lime mixed with the 13·65 tons of wet sludge enabled the whole to be pressed with great ease, yielding about 4 tons of sludge cake.

If the digestion of sludge in the septic tank is calculated in the usual way, by means of the figures for suspended solids in the sewage and septic liquor, in conjunction with the weight of sludge removed from the tank, the result is a digestion of only 1·86 per cent. on the suspended matter in the sewage, as shown by the hourly average samples. This result is certainly incorrect.

When, however, the figures for the volatile or organic matter are taken, instead of the figures for total suspended solids, which include non-volatile matter or grit, the calculation shows a digestion of 16·3 per cent. on the volatile portion of the suspended matter entering the tank as sewage. This shows that the amount of grit which found its way to the experimental tanks in the course of the year was considerably greater than was indicated by the hourly samples of sewage.

Another estimate of the digestion can be based upon the total dry solid matter taken from the settled sewage tank as sludge, added to the dry solid matter leaving the settled sewage tank in the liquor. These, together, should give a total differing by very little from the true value of the dry solid matter entering each tank. The figures are based on a flow of 1,690,000 gallons through each tank.

Dry solid matter taken from settled sewage tank as sludge	4,042 lbs.
,, ,, leaving tank in settled sewage	1,587 ,,
Dry solid matter entering each tank in sewage	5,629
Deduct the dry solid matter leaving septic tank in tank liquor	1,617 ,,
Dry solid matter left in septic tank	4,012 ,,
Dry solid matter taken from septic tank as sludge	1,949 ,,
Digestion of sludge—$\dfrac{(4{,}012-1{,}949) \times 100}{5{,}629}$	36·65 per cent.

This figure is probably very near the true value, but in view of the discrepancy between the solids as calculated from the sewage samples and those removed as sludge, it is safer to state that the septic tank process, as carried out in this experiment, digested *not more than* 36 per cent. of the solid matter in the sewage.

The discrepancy between the solids, as given by the hourly sewage samples and the amounts of sludge taken from the tanks, is probably due to the following cause. The floating weir which controlled the flow of sewage to the tanks is placed immediately against the sluice gates of the screens and catch-pits at the Dorking works. When these gates were changed, in the course of cleaning the screens or emptying the catch-pits, a large amount of heavy detritus must have passed over the weir into the experimental tanks. These disturbances were not properly represented in the hourly sewage samples. Unfortunately this source of error was not detected until late in the year.

* The difference of 153,000 gallons between this amount and that passed through the settled sewage and precipitation tanks is due to the doubling of the flow of sewage to the latter when the spare tank was filling.

SAMPLING OF TANK LIQUORS.

As it was not desired to pass the whole flow of liquor from each tank through its corresponding filter, the surplus was run through a by-pass on to plots of land at a lower level, which also treated the liquor run off when the settled sewage and precipitation tanks were being cleaned.

When all three filters were working at the rate of 120 gallons per cube yard per day, the amount of tank liquor passing to each filter was 2,880 gallons, 2,120 gallons flowing away through the by-pass. From these by-passes the samples of tank liquor were drawn.

Throughout the whole experiment a regular system of average samples, taken every half hour for 3½ hours on every eighth day, was adhered to. The first set of samples was drawn on Tuesday, November 21st, 1905, from 8 a.m. to 11.30 a.m.; the second on Wednesday, November 29th, from 12 noon to 3.30 p.m., and so on throughout the year. The time of drawing was advanced four hours each week, and after six sets had thus been drawn, the seventh was advanced eight hours, so that the samples drawn on a Tuesday for the second time commenced at 12 noon instead of 8 a.m. In this way the strength and character of the sewage as it varied at different times were represented in the average samples.

The eight samples of each tank liquor were mixed in equal quantities, and the average samples thus obtained, if drawn before 12 noon, were at once analysed. If drawn after mid-day, they were placed in the ice-box till the following morning.

The average figures of analysis from the various tank liquors are given in the following tables:—

AVERAGE FIGURES FOR TANK LIQUORS; 40 SETS OF 4 HOURS' AVERAGE SAMPLES IN EACH CASE.

Parts per 100,000.	Settled Sewage. —	Settled Sewage. Average.	Precipitation Liquor. —	Precipitation Liquor. Average.	Septic Tank Liquor. —	Septic Tank Liquor. Average.	Number of Estimations in each case.
Ammoniacal Nitrogen -	(2·33 to 7·96)	4·97	(2·00 to 7·72)	4·76	(2·57 to 7·78)	5·27	(34)
Albuminoid Nitrogen -	(0·37 „ 1·40)	0·84	(0·23 „ 1·14)	0·59	(0.35 „ 1·26)	0·80	(34)
Total Organic Nitrogen -	(0·54 „ 2·84)	1·69	(0·41 „ 2·82)	1·33	(0·79 „ 2·93)	1·74	(15)
Oxidised Nitrogen - -	(0·00 „ 0·28)	0·02	(0·00 „ 0·62)	0·07	—	0·00	(34)
Total Nitrogen - -	(3·16 „ 9·62)	6·59	(2·39 „ 9·29)	5·97	(3·82 to 9·48)	7·08	(15)
Oxygen absorbed at 27° C. at once - - -	(0·66 „ 3·56)	1·97	(0·25 „ 2·72)	1·26	(0·62 „ 3·51)	1·99	(39)
Oxygen absorbed in 4 hours - - -	(3·30 „ 14·67)	7·75	(1·59 „ 11·85)	5·71	(3·23 „ 13·96)	7·70	(40)
Solids in suspension -	(3·6 „ 23·7)	9·39	(2·9 „ 16·7)	6·71	(3·5 „ 20·1)	9·57	(39)

—	Precipitation Liquor; Alumino-ferric alone, 10 grains per gallon.	Average.	Number of Estimations.	Precipitation Liquor; Alumino-ferric & Lime, 10 grains + 5 grains.	Average.	Number of Estimations.
Ammoniacal Nitrogen - -	(2·12 to 7·72)	4·76	(16)	(2·00 to 6·38)	4·76	(18)
Albuminoid Nitrogen - -	(0·23 to 1·04)	0·60	(16)	(0·28 to 1·14)	0·57	(18)
Total Organic Nitrogen -	(0·41 to 2·82)	1·45	(7)	(0·60 to 2·13)	1·23	(8)
Oxidised Nitrogen - -	(0·00 to 0·62)	0·14	(16)		Trace	(18)
Total Nitrogen - - -	(3·08 to 9·29)	6·31	(7)	(2·39 to 8·25)	5·67	(8)
Oxygen absorbed at 27° C. at once - - - -	(0·25 to 2·50)	1·39	(17)	(0·47 to 2·72)	1·15	(22)
Oxygen absorbed at 27° C. in 4 hours - - - -	(1·84 to 11·85)	6·81	(18)	(1·59 to 11·45)	4·82	(22)
Solids in Suspension - -	(2·9 to 16·7)	8·13	(18)	(3·2 to 12·7)	5·49	(21)

TANK LIQUORS.

Settled Sewage and Septic Tank Liquor.

The foregoing figures of analysis show very little difference between the settled sewage and the septic tank liquor. The ammoniacal and total nitrogen in the latter are slightly higher, and there is no oxidised nitrogen. The suspended solids in the septic liquor are

only 0·2 per 100,000 higher than those in the settled sewage ; this is perhaps the point of greatest importance, in comparing these two liquors. It will be observed that the extreme figures are very similar in the two cases, but in this connection it should be noted that while they both varied greatly in strength within the twenty-four hours at the beginning of the experiment (being at some times three or four times as strong as at others*) this variation in the septic liquor decreased as the tank grew mature. During the last six months of the year's working, the ammoniacal nitrogen in the septic liquor varied from 4·28 to 6·90, the corresponding variation for the settled sewage being from 2·58 to 6·78. The suspended matter in the settled sewage remained at a very constant average for the whole year, but the sludging of the tank every four days in the hot weather distinctly reduced the solids leaving the tank. The suspended solids in the septic liquor remained very constant for the first six months, at an average of 8·0 per 100,000. From May 22nd, 1906, the tank became very active, and the suspended solids in the liquor increased greatly, till on July 19th 20·1 parts per 100,000 were found. This was the highest figure for the year. With the return of cooler weather in September, the solids fell again to an average of 8·3 per 100,000.

During the greater part of the year the appearance of the settled sewage and septic tank liquors was very similar, but while the flushes of solid were taking place in the hot weather, the latter contained much fine black suspended matter of quite different character from that in the settled sewage. With regard to smell, the settled sewage usually had a more or less strong sewage smell when drawn, but was never very offensive even in the hottest weather. The septic liquor, on the other hand, had a stale sewage smell during the winter months, which became increasingly offensive, till in July it gave rise to distinct nuisance in the immediate neighbourhood of the outlet channel to the filter. The liquor then gave off much hydrogen sulphide, and left a yellow deposit—probably sulphur—in the channels. The liquid in both settled sewage and septic liquor had a brownish tint, the latter being slightly the darker.

Precipitation Liquor.

As the precipitation liquor differed in many points from the settled sewage and septic liquor, it may be considered separately.

Its figures of analysis for the year show that in suspended solids and the analytical values affected by them, the precipitation liquor is about 30 per cent. weaker than the other tank liquors.

The use of lime and alumino-ferric as precipitants produced much lower figures for suspended solids and "four hours' oxygen absorbed," compared with those produced by alumino-ferric alone. But while the addition of lime gave an undoubtedly better precipitation liquor, no strict comparison can be made between the two methods, as they were not in use at the same time under exactly similar conditions.

The variations in strength of the precipitation liquor during the twenty-four hours followed those of the settled sewage. A small but appreciable amount of oxidised nitrogen derived from the subsoil water in the weak night sewage was usually present in the samples drawn between 4 a.m. and 11.30 a.m.

When alumino-ferric alone was used as a precipitant, a considerable amount of the precipitate always passed out of the tank, and this increased with the time of running since the tank was last cleaned. The addition of lime as precipitant reduced this very appreciably. It may be remarked here that in practical working on the large scale, the strong day sewage with its proportional mixture of precipitant has usually a much slower rate of flow than the average through the tank, owing to the reduction in the flow of sewage during the night. This slow rate of flow assists the settlement of suspended solids, but with the uniform flow adopted in this experiment, no such benefit was derived.

The suspended solids in the precipitation liquor from alumino-ferric alone, which averaged 8·13 per 100,000, were always light coloured and flocculent. They settled readily on standing for one to two hours, leaving an almost colourless, clear, supernatant liquor.

The addition of lime together with alumino-ferric reduced the average suspended solids in the liquor to 5·49 per 100,000. The colour was slightly more brown than before, but there was little flocculent solid. If the means necessary for adding the lime (as milk of lime) automatically and regularly from 8 a.m. to 8 p.m. had been available, the average could have been kept below 5 parts per 100,000, in all probability.

The precipitation liquor always had a typical and not very unpleasant smell. It never gave rise to any nuisance either from the tank or in distribution.

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* Ammoniacal nitrogen in settled sewage 2·23 to 7·96.
„ „ „ septic tank liquor 2·57 to 7·78.

PERCENTAGE REDUCTIONS FOR TANK LIQUORS CALCULATED ON THE HOURLY SEWAGE SAMPLES.

——	Settled Sewage.	Precipitation Liquor; Al.-ferric alone.	Precipitation Liquor; Al.-ferric and Lime.	Septic Liquor.
Ammoniacal Nitrogen	*7	*2	*2	*13
Albuminoid „	16	40	43	20
Total Organic „	20	32	42	18
Total „	2	6	15	*5(?)
"Oxygen absorbed" *in* 4 *hours*	23	32	52	23
Suspended Solids	56	62	74	55

The points of interest in the above table of percentage reductions for the three tank liquors are :—

(1) The similarity in the figures for settled sewage and septic tank liquor.

(2) The superiority of the precipitation liquor over the other two as regards reduction of suspended solids and, consequently, of the figures for organic nitrogen and "oxygen absorbed."

(3) The considerably greater reduction obtained by precipitation with lime and alumino-ferric, as compared with alumino-ferric alone. The 52 per cent. reduction in "oxygen absorbed," when using the two precipitants, is a distinctly satisfactory result.

FILTERS.

The three filters are octagonal in section, constructed of timber framework, each standing on a cemented concrete floor.

The diameter of each filter is 12 feet.
The superficial area of each filter is 12·75 square yards.
The depth of filtering material of each filter is 5 feet 7 inches.
The cubic content of each filter is 23·74 cube yards.

The filtering material consists of clinker ranging from 2 to 4 inches in diameter, resting on a false bottom of perforated tiles. Owing to the local circumstances, the fall given to the separate floors of each filter was not as great as experience showed to be desirable. The small flow of effluent was not sufficient to carry the heavier suspended matter along as quickly as it was deposited on the floor at certain times. The effect of this was to spread the flushes of solid over a longer time than would otherwise have been the case, but with a corresponding reduction in the figures recorded.

The distribution of the tank liquors was effected by three revolving sprinklers. It was found that the smallest rate of flow at which the sprinklers could be kept rotating was one of 2,880 gallons for twenty-four hours. The distribution at this rate, which is equal to 120 gallons per cube yard per day, was not as good as it might have been, owing to the small number of jets falling on each filter. Five holes were used in each sprinkler, and to improve the distribution spreaders were fixed to the three inner holes, so that the jet by impinging upon these was sprayed over a larger area. The conditions were made absolutely alike for all the three filters during the first section of the experiment, when each was working at the rate of 120 gallons per cube yard per day.

When the rate of filtration of the precipitation liquor was increased to 175, and subsequently to 211 gallons per cube yard per day, it became necessary to bring first one, and then two more holes into use. This gave a slightly better distribution than at the 120 gallon rate.

The holes in the sprinkler arms required constant attention, to keep them free from small pieces of fat or other coarse suspended matter brought over in the tank liquors. The sprinkler distributing precipitation liquor naturally gave the least trouble in this respect.

The effluents were led by 3-inch earthenware pipes to a small brick chamber, at which the flow from each filter could be measured by a weir. At these weirs the samples of unsettled effluent were drawn.

* These figures are percentage *increase*.

Sampling of Unsettled Effluent.

The samples of effluent were drawn so as to correspond as nearly as possible with the samples of tank liquor taken in the manner previously described. They were, therefore, drawn about five minutes after the corresponding tank liquors, at intervals of thirty minutes for $3\frac{1}{2}$ hours, or 8 samples for each effluent. The half-hourly samples were mixed in equal quantities, and the average sample thus obtained was at once placed in the ice-box. The effluents were in nearly all cases analysed within forty-eight hours of drawing, *i.e.*, on the day after the analysis of the corresponding tank liquors.

Working of Filters.

The filters began working on November 16th, 1905, and each received a continuous supply of tank liquor at the rate of 120 gallons per cube yard per day. Owing to the somewhat high rate of working and the cold weather, they matured very slowly. In the second week the surface of the clinker on each filter began to show rings of growth in the track of each jet from the sprinkler arms. This growth increased steadily on all the filters, and on December 21st it was sufficient to cause slight ponding on the filter treating settled sewage. On this filter the growth was grey-brown in colour and not very tenacious, and that on the filter treating septic liquor was similar, but rather lighter in colour. On the filter treating precipitation liquor, however, the growth was of a different nature, pinkish-yellow in colour, fleshy, and very tenacious.*

It was considered advisable to rest the filters at this stage. They were, therefore, all three stopped on December 21st, 1905.

During this period the effluents were all of poor quality, with little or no oxidised nitrogen. They failed with one exception to pass the incubator tests. This exception was a sample of effluent from precipitation liquor at the weakest time of the twenty-four hours.

On January 16th, 1906, the filters were again put to work. The growth on the surfaces had dried up to a considerable extent, and those spots where the clinker had been trodden on, in attending to the sprinklers, were forked over.

The effect of the rest was at once evident in the next samples of effluent taken on January 21st. They each contained rather more than 1 part per 100,000 of oxidised nitrogen, which enabled them to pass the incubator tests, notwithstanding a marked increase in the suspended matter in all three. The effluents derived from settled sewage and septic liquor were both brown-tinted, and slightly opalescent. The former had 11·1 parts per 100,000 of well-defined, dark brown suspended matter, which settled readily on standing; the latter 6·9 parts of finer solid, which did not settle so easily. They both had an earthy smell. The effluent from precipitation liquor, on the other hand, was bright and almost colourless, with 8·0 parts of fine brown solid, which settled rapidly. It had a very clean earthy smell, and was distinctly the best effluent of the three.

The filters were kept working continuously, and as they matured the effluents improved in quality, but maintained the relative characteristics of the samples described above. The suspended matter decreased in all three effluents, but especially in that from the filter treating precipitation liquor, so that on February 22nd the latter contained only 1·5 parts per 100,000, while the "settled sewage" and "septic" filter effluents contained 4·6 and 6·8 parts respectively. This fact is of importance in view of what was happening upon the surface of the filters. The growths, as previously described, had again flourished exceedingly on all the filters, but were not thick enough upon either the settled sewage or septic filter to interfere with the aeration or to cause any ponding. On the "precipitation" filter, however, the fleshy nature of the growth caused it to fill the interstitial spaces along the track of each jet from the sprinkler, so as to cause local ponding and impede the surface aeration. From this time the nitrifying power of the filter began to deteriorate, so that on March 3rd the effluents contained :—

From	(1) Settled Sewage.	(2) Precipitation Liquor.	(3) Septic Liquor.
Oxidised Nitrogen - - - -	2·57	1·93	2·41

while on March 11th the suspended matter in each case was :—4·9, 0·6, 5·9.

* A sample of growth collected from the coarse filters treating precipitation liquor in March, 1908, was identified as "Cladothrix dichotoma, Cohn," by Dr. Massee, of the Royal Gardens, Kew.

The effluent from precipitation liquor now began to show opalescence, and on March 27th, when the surface growth had reached its maximum development, the incubated sample became putrid.

The more important figures of analysis for the three effluents, drawn at this date, are given below. They are from a very strong soapy sewage containing 9 parts of (total) nitrogen per 100,000, and giving a "four hours' oxygen absorbed" figure of 15, approximately.

—	Effluent from Settled Sewage.	Effluent from Precipitation Liquor.	Effluent from Septic Liquor.
Ammoniacal Nitrogen	3·06	4·34	3·15
Albuminoid ,,	0·28	0·32	0·33
Oxidised ,,	2·18	1·04	2·27
"Oxygen absorbed" *in* 4 *hours*	2·92	3·17	2·86
Dissolved Oxygen taken up *in* 24 *hours*	0·99	1·70	0·94
Incubator tests	Passed.	Failed.	Passed.
Suspended solids	2·3	2·3	3·9

From the above table it will be seen that, while the figures for ammoniacal and oxidised nitrogen show quite clearly the effects of deficient aeration in the precipitation filter, those for albuminoid nitrogen and four hours' "oxygen absorbed" give little indication of this, in comparison with the results from the other two filters. On the other hand, the twenty-four hours' aeration test brings out the difference very plainly. The albuminoid nitrogen and "oxygen absorbed" figures must be compared with those for the normal effluent from precipitation liquor, to bring out their inferiority. This important point will be referred to again when, considering the whole of the results for this section of the experiment (*cf.* p. 183).

For three weeks from this date the "precipitation" effluent continued to be putrescible, and samples had a bad or doubtful smell when drawn. On March 30th some strings of light grey suspended matter were noticed in the effluent, which proved on examination to be some kind of growth, apparently dead or dying. This washing out process continued for two or three weeks, some large masses of growth blocking the 3-inch pipe leading from the filter, so that it had to be frequently cleaned out.

This dead growth differed from that which had flourished, and was still present, upon the surface of the filter. It was of a loose, fibrous nature, and showed a mass of fine hyphae under the microscope. It putrefied on incubation.

On April 13th the last bad sample was drawn from the "precipitation" filter. The following table of figures for the twenty-four hours' aeration test on the paper-filtered and original effluent shows that the liquid portion of the precipitation effluent, as distinct from the dead growth or other suspended matter, was not well purified.

—	Effluent from Settled Sewage No. 111.	Effluent from Precipitation Liquor. No. 112.	Effluent from Septic Liquor. No. 113.
Dissolved Oxygen taken up *in* 24 *hours* at 18°C. by original sample	0·95	1·88	1·16
Dissolved Oxygen taken up *in* 24 *hours* at 18°C. by paper filtered sample	0·52	1·33	Probably 0·6*
Suspended solids	2·6	3·0	2·9

* Owing to an accident, the exact figure cannot be given.

While the filter treating precipitation liquor was suffering from this choking by growth and its subsequent discharge, the other two filters gave no sign of deficient aeration, nor was there any appreciable discharge of solids in their effluents. As, however, by the end of April the surfaces of both the settled sewage and septic filters were practically free from growth, it is probable that the same phenomena which deranged the precipitation filter took place in their case, but on a very much reduced scale. The growth on the precipitation filter was still thick enough to cause local ponding, but it showed no recent increase. The aeration of the filter now began to improve, for a sample of effluent drawn on April 21st was of good quality, well nitrated, and passed the incubator tests.

On May 2nd the tank liquors were shut off and the filters all rested for seven days in warm, dry weather. The object of this rest was to dry up the growth on the precipitation filter, and enable it to be washed through more readily.

The question naturally arises as to why the precipitation liquor should favour this luxuriant growth so much more than the other tank liquors. It is possible that the relative weakness of the precipitation liquor, containing as it did at this time a small amount of nitrate derived from the subsoil water, assisted the growth of the fungus; but further investigation is required before this question can be definitely answered.

On May 9th the filters were started again after the seven days' rest. The growth on the settled sewage and septic filters had practically disappeared, while on the precipitation filter it had shrivelled up very much. A great quantity of suspended matter now came down from all three filters, especially from that treating precipitation liquor. The solids were well aggregated and settled thickly on the floors of the filters, which had not fall enough to carry them down to the effluent pipes as quickly as they were deposited from the filter. No more dead growth in masses came out from the precipitation filter, but much light-brown suspended matter which settled quickly. Apart from suspended solids this effluent was now satisfactory. It contained 1·8 parts per 100,000 of oxidised nitrogen and passed the incubator tests. The climax of the flush-out of suspended matter was reached on May 22nd. Samples taken from 8 to 11.30 p.m. gave very high figures for suspended matter, the 34·0 parts per 100,000 in the precipitation effluent being by far the highest figure recorded during the year's working. It is important to notice that, notwithstanding the excessive quantity of solids in all the effluents, they passed the incubator tests. The effluent from the precipitation filter, however, only just passed.

The greater part of this flush-out of suspended solids evidently consisted of matter retained in the filter during the period of maximum growth in the early spring, when the suspended solids fell to 0·6 per 100,000, and did not exceed 4·0 for twelve consecutive weeks. The precipitation liquor was putting 7·11 parts per 100,000 on to the filter throughout this period.

A large number of fine white worms appeared at this time in all the filter effluents, but there were considerably less in the precipitation effluent than in the other two. These were followed by flies in great quantity.

The warm dry weather experienced during June suited the filters admirably. The ammoniacal nitrogen fell to 1·5 per 100,000, while the oxidised nitrogen rose to 3·0 in all the effluents. The solids, however, kept at about 7 parts per 100,000 in each effluent, thus causing the "oxygen absorbed" and other figures affected by them to remain at a high average.

On July 5th this section of the experiment was brought to an end. The results obtained for *all* samples drawn from February 6th to July 2nd, 1906, are given in the following table.

TABLE No. 1.

TABLE OF AVERAGE FIGURES OF ANALYSIS FOR EFFLUENTS FROM FILTERS TREATING SETTLED SEWAGE, PRECIPITATION LIQUOR AND SEPTIC TANK LIQUOR, EACH AT THE RATE OF 120 GALLONS PER CUBE YARD PER DAY. ALL SAMPLES INCLUDED.

Parts per 100,000.	Effluent from Settled Sewage.	Average.	Effluent from Precipitation Liquor.	Average	Effluent from Septic Tank Liquor.	Average.	Number of Estimations in each case.
Ammoniacal Nitrogen	(0·96 to 3·74)	2·23	(0·69 to 4·34)	2·43	(0·88 to 4·11)	2·10	(14)
Albuminoid Nitrogen	(0·19 to 0·62)	0·33	(0·08 to 0·68)	0·27	(0·19 to 0·62)	0·34	(14)
Total organic Nitrogen	(0·29 to 1·42)	0·78	(0·21 to 1·67)	0·74	(0·41 to 1·22)	0·74	(7)
Oxidised Nitrogen	(1·31 to 3·29)	2·37	(0·80 to 3·18)	1·92	(1·66 to 3·30)	2·49	(14)
Total Nitrogen	(3·52 to 6·75)	5·32	(2·96 to 6·87)	5·12	(3·86 to 7·18)	5·38	(7)
"Oxygen absorbed" *at* 27°C. *at once*	(0·59 to 1·81)	0·92	(0·21 to 2·17)	0·68	(0·55 to 2·10)	0·96	(18)
"Oxygen absorbed" *in 4 hours*	(2·01 to 5·99)	3·37	(0·81 to 6·99)	2·61	(1·76 to 6·10)	3·51	(18)
Dissolved oxygen taken up *in 24 hours* at 18° C.	(0·24 to 1·56)	0·82	(0·10 to 2·82)	0·93	(0·36 to 1·44)	0·82	(15 to 16)
*Dissolved oxygen taken up *in 5 days* at 18° C.	(1·24 to 7·83)	3·91	(0·55 to 12·96)	3·63	(1·20 to 6·41)	3·73	(13 to 14)
Incubator test (by smell)	18 passed 0 failed		14 passed 3 failed 1 doubtful		18 passed 0 failed		(18)
Solids in suspension	(1·6 to 10·7)	5·97	(0·6 to 34·0)	7·00	(1·3 to 11·4)	6·44	(18)

* 2 samples of effluent from settled sewage
3 samples of effluent from precipitation liquor
4 samples of effluent from septic tank liquor
} exhausted all the oxygen available in the diluting water.

On considering the results given in Table No. 1, it is evident that the effluents from the filters treating settled sewage and septic liquor, respectively, are for all practical purposes identical.

The greatest difference is in suspended solids, the figure for which is slightly higher in the effluent from septic liquor. The figure for dissolved oxygen taken up in five days by this effluent is lower than the reality; the effluent had exhausted all the available oxygen in four out of thirteen estimations.

All the eighteen samples of each of these two effluents were quite sweet after five days' incubation, although the ratio of oxidised to unoxidised nitrogen was not a high one. This ratio was a steadily increasing one throughout this section of the experiment, as the filters matured with the rising of the atmospheric temperature from February to July.

Taken all round these effluents are of fair quality, but require to have their suspended matter reduced at least 50 per cent., either by subsequent settlement or fine filtration.

The figures given in the centre column for the effluent from the filter treating precipitation liquor are far less easily compared with those for the other two effluents. The effects of the fungoid growth upon five out of the eighteen samples are great enough to entirely change the relative position of many of the figures. To show this clearly another Table, No. 1A, is given.

Three of the five bad samples, Nos. 96, 105, and 112, taken in April, were very poorly oxidised owing to the choking of the filter, but they contained little suspended matter. The other two samples, Nos. 146 and 154, taken four and five weeks later, contained excessive amounts of dead growth and other suspended matter previously held up by the filter. The first three all putrefied on incubation. One of the other two, No. 154, gave a doubtful result, probably from unascertained causes.

Samples Nos. 146 and 154 raised the average figure for suspended matter very considerably. They contained 34 and 24 parts of suspended matter respectively.

The most interesting point in connection with the effluent from precipitation liquor is the relation between the "oxygen absorbed" from permanganate and the dissolved oxygen taken up from tap-water in the aeration tests. Unfortunately the capacity of the effluents to take up oxygen was under-estimated in some cases, so that the average figures for five days' aeration are in each case lower than the true value, especially in the effluent from precipitation liquor. They show, however, that *at least* that amount of oxygen stated was taken up. The twenty-four hours' estimations, are correct, as there was an excess of available oxygen in every case. It will be noticed that while the "oxygen absorbed" figures for the effluent from precipitation liquor are much lower than those for either of the other two effluents, the reverse is the case with the figures for dissolved oxygen taken up in twenty-four hours, and this would undoubtedly have also held for the five days' estimations, if enough oxygen had been given to all the samples. It may be stated here that this relation holds good in all the comparative samples examined during the year's working. It is of considerable importance with regard to the question of standards. For, an effluent derived from a precipitation process would be passed on the "oxygen absorbed" test, while effluents derived from other processes would be condemned, although as regards their absorption of dissolved oxygen they might be the better samples. This result is due to the difference in the character of the suspended matter in the two types of effluent, for in the paper filtered samples there is a fairly close agreement between the "oxygen absorbed" and aeration tests. (*cf.* Table No. 3.)

Although three samples of effluent from the filter treating precipitation liquor failed to pass the incubator test, the figures given in Tables 1A, 2 and 3, show that this effluent would have maintained a very high standard of purity if the experiment had continued under the same conditions for a whole year after the filter was once matured. It is, of course, possible that by resting the filters at suitable times, the growth might be kept down to such limits that the extreme conditions of the experiment, which has just been detailed, would never arise.* The flexibility of the process as regards the amount of liquor capable of treatment on a given capacity of the filter is here in its favour, as it would enable one or more filters to be rested while the others were worked temporarily at an increased rate.

* *See* Part III.; also Sixth Report of the Commission, App. II., p. 24.

TABLE No. 1A.

TABLE OF AVERAGE FIGURES OF ANALYSIS FROM THE SAME SAMPLES AS IN TABLE NO. I, BUT WITH 5 SAMPLES OF EFFLUENT FROM THE FILTER TREATING PRECIPITATION LIQUOR OMITTED. THE CORRESPONDING SAMPLES OF EFFLUENT FROM THE FILTERS TREATING SETTLED SEWAGE AND SEPTIC TANK LIQUOR ARE ALSO OMITTED, TO MAKE THE TABLE STRICTLY COMPARATIVE.

Parts per 100,000.	Effluent from Settled Sewage.	Average.	Effluent from Precipitation Liquor.	Average.	Effluent from Septic Tank Liquor.	Average.	Number of Estimations in each case.
Ammoniacal Nitrogen - -	(0·96 to 3·44)	1·91	(0·69 to 3·80)	2·02	(0·88 to 3·39)	1·70	(11)
Albuminoid Nitrogen- - -	(0·19 to 0·46)	0·30	(0.08 to 0·30)	0·21	(0·19 to 0·50)	0·31	(11)
Oxidised Nitrogen - - -	(1·31 to 3·29)	2·48	(1·40 to 3·18)	2·12	(1·66 to 3·30)	2·55	(11)
Oxygen absorbed at 27° C. *at once*	(0·59 to 1·58)	0·86	(0·21 to 0·95)	0·46	(0·55 to 1·51)	0·85	(13)
Oxygen absorbed at 27° C. *in 4 hours*	(2·01 to 4·37)	3·04	(0·81 to 3·21)	1·80	(1·76 to 5·34)	3·19	(13)
Dissolved Oxygen taken up *in* 24 *hours* at 18° C.	(0·24 to 0·97)	0·63	(0·10 to 0·96)	0·50	(0·36 to 1·39)	0·72	(10 to 11)
Dissolved Oxygen taken up in 5 *days* at 18° C.	(1·24 to 6·01)	3·24	(0·55 to 4·59)	2·25	(1·20 to 5·84)	3·27	(9 to 10)
Incubator Test (by smell) - -	13 passed, 0 failed		13 passed, 0 failed		13 passed, 0 failed		(13)
Solids in suspension - - -	(1·6 to 10·6)	6·15	(0·61 to 8·7)	4·50	(1·3 to 11·4)	6·79	(13)

Increased Rate of Filtration for Precipitation Liquor.

As the results of the previous experiments showed that the normal effluent from the filter treating precipitation liquor was approximately 33 per cent. better than either of those from the other processes, as judged by the four hours "oxygen absorbed" test, it was decided to increase the rate of filtration in the case of this liquor. On July 5th the flow of tank liquor to this filter was raised to 4,200 gallons per twenty-four hours, or 175 gallons per cube yard per day. This rate of working was continued until August 28th, the settled sewage and septic liquor being continued at the same rate as before, viz., 120 gallons per cube yard. The weather was extremely hot throughout this period. The septic tank was in great activity, so that large amounts of suspended matter passed on to the filter, and there was a marked increase in the solids coming out with the effluent from this filter, as much as 16·5 parts per 100,000 being estimated on August 12th.

On the other hand, the solids in the effluent from settled sewage showed no tendency to increase, but remained at about 4 parts per 100,000, or rather below its average figure.

The increased rate of filtration caused no deterioration in the effluent from precipitation liquor. It continued to be easily the best effluent of the three. The amount of dissolved oxygen taken up in five days was the only point of inferiority to the effluent from settled sewage. This was due to the suspended matter, to which this test is especially sensitive.

TABLE No. 2.

Samples drawn July 11th to August 20th, 1906.

TABLE OF AVERAGE FIGURES OF ANALYSIS FOR EFFLUENT FROM FILTER TREATING PRECIPITATION LIQUOR AT 175 GALLONS PER CUBE YARD PER DAY, AND FOR EFFLUENTS FROM FILTERS TREATING SETTLED SEWAGE AND SEPTIC TANK LIQUOR, EACH AT 120 GALLONS PER CUBE YARD.

Parts per 100,000.	Effluent from Settled Sewage.	Average.	Effluent from Precipitation Liquor.	Average.	Effluent from Septic Tank Liquor.	Average.	Number of Estimations in each case.
Ammoniacal Nitrogen - - -	(0·56 to 1·56)	1·05	(0·23 to 1·30)	0·81	(1·26 to 2·19)	1·66	(5)
Albuminoid Nitrogen - - -	(0·12 to 0·32)	0·25	(0·13 to 0·28)	0·19	(0·35 to 0·51)	0·43	(5)
Total Organic Nitrogen - -	(0·52 to 0·71)	0·65	(0·44 to 0·79)	0·57	(0·43 to 0·86)	0·70	(3)
Oxidised Nitrogen - - -	(1·62 to 4·04)	2·66	(2·28 to 3·64)	2·93	(2·22 to 4·02)	2·93	(5)
Total Nitrogen - - - -	(3·16 to 5·53)	4·50	(3·23 to 5·10)	4·47	(4·48 to 5·92)	5·37	(3)
Oxygen absorbed at 27° C. *at once*	(0·40 to 1·27)	0·74	(0·28 to 0·92)	0·62	(1·14 to 1·92)	1·59	(6)
Oxygen absorbed at 27° C. *in 4 hours*	(1·34 to 3·99)	2·65	(0·90 to 2·91)	1·80	(3·95 to 6·44)	5·13	(6)
Dissolved Oxygen taken up *in* 24 *hours at* 18° C.	(0·45 to 0·88)	0·71	(0·22 to 0·98)	0·52	(0·30 to 1·88)	1·20	(5)
Dissolved Oxygen taken up *in* 5 *days* at 18° C.	(2·09 to 4·59*)	3·44	(2·76 to 4·77*)	3·82	(5·09 to 7·04)	6·39	(4)
Incubator Test (by smell) - -	6 passed, 0 failed		6 passed, 0 failed		6 passed, 0 failed		(6)
Solids in suspension - - -	(0·6 to 7·6)	4·16	(1·8 to 6·4)	4·30	(6·4 to 16·5)	10·44	(5)

* One sample of effluent from settled sewage and two from precipitation liquor exhausted all the oxygen available.

Table No. 2 gives the average figures for the samples drawn while the precipitation liquor was being filtered at the rate of 175 gallons per cube yard. These samples were drawn in the height of summer, and bring out certain points which are in marked contrast to the results given in Tables 1 and 1A :—

(1) The great reduction in ammoniacal nitrogen in all three effluents, but especially in that from precipitation liquor, accompanied by an increase in oxidised nitrogen in a lesser degree.

(2) The fall in the "oxygen absorbed" for the settled sewage and precipitation filter effluents, due to the increasing efficiency of the filters and their freedom from growths. At the same time an increase from 0·96 to 1·59 in the "oxygen absorbed" at once (largely due to nitrous nitrogen), and from 3·51 to 5·13 in the four hours test for the effluent from the filter treating septic tank liquor. These last results were due to the activity of the septic tank, with the consequent increase of solids in the effluent, as previously described.

(3) The dissolved oxygen absorption tests accord with the figures for oxygen absorbed from permanganate, with again the exception of the five days' figure for the effluent from precipitation liquor. This is slightly higher than that for the effluent from settled sewage, while the four hours "oxygen absorbed" is 32 per cent. lower.

(4) The high figure, 10·44 parts, for suspended matter in the septic filter effluent, with its influence on the other figures of analysis. Its cause has been already considered.

On August 28th the rate of filtration of the precipitation liquor was still further increased, the whole of the flow from the tank, viz., 5,000 gallons per day, being passed through the filter. This is equivalent to 211 gallons per cube yard per day.

The effluent continued to be satisfactory, but showed a slight increase in ammoniacal nitrogen, while both the effluents from settled sewage and septic liquor maintained the improvement that had been in progress throughout the year.

The activity of the septic tank abated after the first week of September, so that considerably less suspended matter passed on to the filter. The effluent showed a marked improvement in consequence.

The appearance of the effluents at this time was as follows:—The effluent from settled sewage was very bright, but slightly brown-tinted, with a very clean earthy smell.

The effluent from precipitation liquor was slightly opalescent, with less colour than the others, but not quite so clean a smell.

The effluent from septic liquor was the most coloured of the three, but fairly bright looking, and it had an earthy smell.

Towards the end of October rings of growth appeared on the precipitation filter, and a little later upon the settled sewage filter. They were similar to those which formed at the beginning of the experiment in the previous autumn. The septic filter showed only faint rings under each jet. When the experiment ended on November 15th, 1906, the surface of the dry clinker was practically clean on the settled sewage and septic filters, the precipitation filter having a very thin yellowish coating.

TABLE No. 3.

Samples drawn August 29th to November 10th, 1906.

TABLE OF AVERAGE FIGURES OF ANALYSIS FOR EFFLUENT FROM FILTER TREATING PRECIPITATION LIQUOR AT 211 GALLONS PER CUBE YARD PER DAY, AND FOR EFFLUENTS FROM FILTERS TREATING SETTLED SEWAGE AND SEPTIC TANK LIQUOR, EACH AT 120 GALLONS PER CUBE YARD.

Parts per 100,000.	Effluent from Settled Sewage.	Average.	Effluent from Precipitation Liquor.	Average.	Effluent from Septic Tank Liquor.	Average.	Number of Estimations in each case.
Ammoniacal Nitrogen	(0·07 to 1·93)	0·76	(0·18 to 1·97)	1·09	(0·22 to 1·96)	1·09	(9)
Albuminoid Nitrogen	(0·14 to 0·24)	0·19	(0·08 to 0·25)	0·16	(0·13 to 0·37)	0·22	(9)
*Total Organic Nitrogen	(0·14 to 0·65)	0·33	(0·18 to 0·62)	0·32	(0·20 to 0·64)	0·36	(3)
Oxidised Nitrogen	(2·16 to 4·26)	3·11	(1·63 to 4·09)	2·93	(3·06 to 4·80)	3·65	(9)
*Total Nitrogen	(2·89 to 5·20)	3·78	(2·26 to 5·22)	3·52	(4·71 to 5·22)	4·96	(3)
Oxygen absorbed at 27° C. *at once*	(0·44 to 1·24)	0·84	(0·44 to 0·76)	0·60	(0·59 to 1·66)	1·17	(10)
Oxygen absorbed at 27° C. *in 4 hours*	(1·44 to 2·96)	2·29	(1·25 to 2·33)	1·75	(1·99 to 3·70)	2·85	(10)
Dissolved Oxygen taken up at 18° C. *in 48 hours*	(0·70 to 1·44)	0·94	(0·50 to 1·64)	1·09	(0·23 to 1·48)	0·71	(6 to 7)
Dissolved Oxygen taken up at 18° C. *in 5 days*	(1·10 to 3·54)	1·86	(1·18 to 4·22†)	2·63	(0·72 to 4·10)	2·07	(10)
Incubator Test (by smell)	10 passed, 0 failed		10 passed, 0 failed		10 passed, 0 failed		(10)
Solids in suspension	(1·5 to 6·3)	3·88	(1·7 to 7·3)	4·18	(1·9 to 6·1)	3·97	(10)
Paper Filtered Samples.							
Oxygen absorbed *in 4 hours*	(1·09 to 2·26)	1·67	(0·76 to 1·58)	1·24	(1·43 to 2·72)	2·04	(9)
Dissolved oxygen taken up *in 5 days*	(0·48 to 1·08)	0·70	(0·37 to 1·05)	0·60	(0·28 to 0·81)	0·63	(9)

* These results are strictly comparative, but being from 3 samples only in each case are not true averages.
† This sample exhausted all the oxygen available.

In Table No. 3 the average figures are given for the samples taken during this last section of the experiment. They show that the effluent from precipitation liquor, filtered at the rate of 211 gallons per cube yard, is still superior to either of the other two effluents filtered at 120 gallons per cube yard, when judged by the albuminoid nitrogen or "oxygen absorbed" test, the latter applying to both the original and the paper-filtered samples. The superiority is now, however, much less marked, and any further increase in the rate of filtration up to, say, 230 gallons per cube yard, would probably have given an effluent of quality similar to those from settled sewage and septic liquor at half this rate of working, *when judged by the above-mentioned standards.*

On the other hand, if the figures for dissolved oxygen absorption are taken as a standard, the effluent from the filter treating precipitation liquor is now inferior to the other two effluents, suspended solids included; but as regards the paper-filtered samples *i.e.* the liquid portions alone, the effluent from precipitation liquor is still the best of the three.

This again confirms the fact, before noticed, that the dissolved oxygen absorption test is more severe than the tests for albuminoid nitrogen and "oxygen absorbed" from permanganate, when applied to the precipitation filter effluent in comparison with those from settled sewage and septic liquor.

Table No. 4 summarises the "work done" by the filters during the year. For a detailed explanation of this table, the memorandum "on the estimation of work done by filters,"* by Dr. McGowan and Mr. Frye, should be referred to. It is necessary, however, to call attention to the figures for relative purification effected by a cube yard of filter, given in column G. It will be seen that the filters treating settled sewage and septic tank liquor each effected 8,500 "units of purification," and gave 89 and 86 per cent. purification, respectively, when working at the rate of 120 gallons per cube yard throughout the year. The filter treating precipitation liquor cannot be directly compared with the other two, on account of the alterations in the rate of flow. The fact that 10,800 "units" were effected by this filter, with 93 per cent. purification, when working at 211 gallons per cube yard, makes it appear the most efficient of the three; whereas this high efficiency is really due to the maturity of the filter and the favourable atmospheric conditions existing during this section of the experiment. The mean efficiency of a cube yard of the filter treating precipitation liquor, in the three sections at 120, 175 and 211 gallons per cube yard, is just under 8,000 units, and the mean purification is 82 per cent. The conclusion may, therefore, be drawn that a cube yard of filter will effect very similar purification as regards "work done," when treating either of the three types of tank liquor; the actual efficiencies are in the order: (1) Settled sewage; (2) septic tank liquor; (3) chemical precipitation.

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* This Appendix, p. 10.

TABLE No. 4.

Showing the work done by the filters when treating the various tank liquors, based on the calculated "strengths" of the liquors and of the corresponding effluents.*

A.	B.	C. Filter Effluent; Figures of Analysis.				D. Strength or Oxidizability of Filter Effluent :—			E.	F.	G.	G. 1. Percentage Purification :—				H.
Nature of liquor treated.	Calculated strength of liquor treated.	Ammoniacal + Organic Nitrogen.	Volatile Solids.	"Oxygen absorbed from Permanganate in 4 hours.	Nitric Nitrogen.	(a) Whole Effluent, Including Suspended Solids.	(b) Effluent without Suspended Solids.	(c) Effluent without Suspended Solids and Nitrate.	Oxygen used up in producing this Effluent (B.—D.)	Gallons of liquor treated per cube yard of filter per day (constant flow).	Units of Purification per cube yard of filter.	(a) On Atmospheric Oxygen taken up in the process.	(b) On Atmospheric Oxygen taken up, leaving out of account the Suspended Solids of the Effluent.	(c) On Atmospheric Oxygen taken up, leaving out of account the Suspended Solids and Nitrate of the Effluent.	(d) On "Oxygen absorbed" from Permanganate in four hours (including the Suspended Solids of the Effluent).	General quality of Effluent (considered from the standpoint of a final Effluent, *per se*).
Settled Sewage November, 1905 to November, 1906.	80·1	2·19	3·88	2·93	2·6	8·8	1·0	8·8	71·3	120	8,556	89	99	89	62	Fair. Filter was maturing throughout this experiment.
Septic Liquor November, 1905 to November, 1906.	81·6	2·34	4·67	3·60	2·9	11·2	1·8	10·5	70·4	120	8,448	86	98	87	53	Moderate. Filter was maturing throughout this experiment.
Precipitation Liquor																
Experiment I. 10 grains Alumino-ferric. February 6th to July 2nd, 1906.	68·8	3·17	4·77	2·61	1·9	18·1	8·6	14·3	50·7	120	6,084	74	88	79	62	Not very good. This purification was affected by growths. Filter not really quite matured during this experiment.
Experiment II. 5 grains Lime + 10 grains Alumino-ferric. July 11th to August 20th, 1906.	53·5	1·38	2·98	1·8	2·9	3·5	—2·5	6·2	51·8	175	9,065	93	105	89	62	Very fair or fair.
Experiment III. 5 grains Lime + 10 grains Alumino-ferric. Aug. 29th to Nov. 10th, 1906	55·3	1·41	3·14	1·75	2·9	3·9	−2·6	6·3	51·4	211	10,845	93	105	90	62	Very fair or fair.

* Cf. Memoranda by Dr. McGowan and Mr. Frye; this App., pp. 1 and 10.

EFFLUENT SETTLING TANKS.

Four small rectangular tanks, each holding 411 gallons, were used to settle the suspended solids coming out in the effluent from the three filters.

These tanks were all of the same size, with a depth of two feet. Two of them were connected with the sand filter and two with the sterilization tank.

From the beginning of the experiment on November 16th, 1905, to March 1st, 1906, the combined effluents from the three filters were run through tanks Nos. 1 and 2, worked in parallel as one tank. This was equivalent to two hours sixteen minutes continuous flow settlement when the tanks were clean. In the last week of February the accumulated solids began to rise to the surface, showing that fermentation was taking place. The flow of effluent through these tanks was therefore stopped. On emptying the supernatant effluent there remained 13·75 inches of very dark-brown mud. This had a strong and rather unpleasant earthy smell. Samples of this mud gave the following figures :—

Dry solids - - - - - - - -	6·01 per cent.
Volatile matter in these solids - - - -	2·62 ,,
Non-volatile ,, ,, ,, - - - -	3·39 ,,
Moisture - - - - - - - -	93·99 ,,

The removal of this mud was accomplished by bailing out with pails and pouring the contents into two bays, formed on the ground near the tanks. It took some two months to dry completely, and during part of the time gave rise to an unpleasant smell in the immediate neighbourhood of the bays. It must, however, be remembered that the solids which formed this mud were derived from the unmatured or imperfectly matured filters. When air-dry, this mud became a friable mass with a clean earthy smell.

The result of settlement of the combined effluents, up to this first cleaning of the settling tanks, is given in the table below :—

Suspended Solids.	Parts per 100,000.
Average for Combined Unsettled Effluents. 6·61 (2·6 to 10·2) (8 Estimations).	Average for Settled Effluents (2¼ hours continuous flow). 3·87 (2·6 to 5·6) (6 Estimations).

This gives a reduction of 41 per cent. in the suspended solids of the unsettled effluents.

From March 1st there was a considerable improvement in the efficiency of the settlement. But during April, while the effluent from the filter treating precipitation liquor was putrescent and contained much dead growth, it was separated from the other two effluents. If allowed to mix with them as usual, the combined settled effluent would not pass the incubator test. A four hours average sample of the combined settled effluent, No. 107, taken under the above conditions from 8 p.m. to 11.30 p.m., on April 4th, 1906, was a very poor sample in every respect, although the effluents from settled sewage and septic liquor were of fair quality at the time, containing as they did 1·75 and 2·14 parts of oxidised nitrogen respectively.

Owing to the exposed position of the settling tanks and their shallowness, it was found that the temperature of the effluent rose considerably in its passage through them, under the direct rays of the sun at mid-day. Thus, on June 22nd the combined effluent entering tanks Nos. 3 and 4 had a temperature of 17°C., but after two and a quarter hours flowing settlement the reading was 21°, as taken at the outlet to sand filter. Under these conditions fermentation of the settled solids was greatly accelerated, so that after working for a week in the warm summer weather, particles of the previously deposited solid began to rise to the surface. They were lifted by small bubbles of gas which, on discharge at the surface, allowed the solid to sink again. Those particles which rose near the outlet were carried away by the effluent, just as in the case of the septic tank solids, previously described. These adverse conditions were due to the experimental scale of working. With a larger body of effluent and weekly removal of the deposit, no trouble from this cause would probably occur. Even under the conditions of the experiment, the highest figure noted for suspended matter in the settled effluent was 4·6. This was given by a four hours average sample, No. 156, taken from 12 midnight to 3.30 a.m. on May 31st. The filters were then discharging solids after a week's rest, as described on page 182.

After June 22nd a more rapid flow was tried, with a view to keeping the effluent cooler. Only one tank was now used, instead of two in parallel. This gave one hour eight minutes flowing settlement. The result was satisfactory, both as regards the removal of suspended

matter and the time the tank could be run without cleaning. The suspended solids averaged 2·5 parts in the settled effluent, while the tanks were changed for cleaning every fourteen days.

In the first week of August the suspended solids in the effluent from the filter treating septic liquor began to increase rapidly in amount and fermentability. As this interfered with the successful settlement of the combined effluents, the "septic" effluent was run separately through one settling tank on August 10th. This unsettled effluent contained fifteen parts of suspended solids, the greater part of which settled immediately, during the first twelve hours after starting the tank. The time of settlement was three hours twenty-four minutes continuous flow. On the morning of the next day, August 11th, the settled effluent was unsatisfactory, fermentation of the deposited solids having already visibly commenced At noon, on the same day, the whole of the solids rose to the surface, with considerable discharge of gas. The weather was warm at this time, but by no means the hottest of an exceptionally fine summer.

As settlement of the "septic" filter effluent solids under these conditions was an unsuitable method for reducing suspended matter, the filtration of the effluent through shallow beds of fine material was substituted in this case. Details of this experiment are given below.

From this date only the effluents from the filters treating settled sewage and precipitation liquor were passed through the settling tanks. An increased volume of the latter was, however, dealt with, so that the time of settlement remained approximately the same. No difficulty was experienced in settling the solids from these effluents.

The total volume of deposited solids removed from the settling tanks during the experiment was 13·61 cube yards, 3,300,000 gallons of effluent, approximately, having been passed through the tanks.

Weight of wet mud—10·39 tons, approximately.
„ dry solid— 0·49 „ „

In all cases the deposit was pumped into bays and dried as before described, but after the first emptying of the tank in March, there was no nuisance from smell of any kind, either in pumping or drying. In the very hot weather, however, the freshly pumped deposit gave off an earthy but not unpleasant smell.

Average Figures of Analysis for Combined Settled Effluent, February 6th to October 17th, 1906.

Parts per 100,000.	Average.	Number of Estimations.
Oxygen absorbed at once at 27° C.	0·63	31
„ „ in 4 hours „	2·01	33
Dissolved Oxygen taken up in 24 hours at 18° C.	0·60	22
„ „ „ „ 5 days „ „	2·63	21
Incubator Test (by smell)	30 passed, 1 failed	31
Solids in suspension	2·32	23

STRAINING BEDS FOR SEPTIC FILTER EFFLUENT.

As settlement of the suspended solids in the effluent from the filter treating septic liquor became practically impossible during the hot weather of 1906, two small straining beds of fine material were constructed to deal with this effluent separately.

The beds were made by placing 6-inch boards around a concrete floor, 12 feet by 6 feet, with a partition across the centre dividing it into two 6-feet squares. The floor had a slight fall towards two 2-inch outlet pipes, passed through the board on that side. The bottom and joints of the beds were cemented watertight.

One bed was filled with a 3-inch layer of $\frac{1}{4}$-inch clinker, covered by 3 inches of very fine clinker ($\frac{1}{16}$-inch and under). The other was filled with 6 inches of $\frac{1}{8}$-inch clinker, with no fine material. No special distribution was employed, beyond making shallow grips on the surface of the bed. The effluent from the filter treating septic liquor was run on to the beds at the rate of 720 gallons per *square* yard of straining surface. No. 1 Bed, with the fine material on top, was first brought into use. It ran for ten days before flooding the sides of the bed, and during the greater part of this time the outflowing effluent was practically free from suspended solids. It gave 3 to 5 volumes of mud per 100,000 by centrifuge, equivalent to 0·3 to 0·5 part of suspended solids per 100,000 by weight. The unsettled effluent had 4·7 parts by weight.

The effluent was now turned on to Bed No. 2, filled with the coarser material throughout. This behaved exactly as anticipated, *i.e.*, it gave an effluent similar to that produced by the settling tanks, with 2·0 parts of suspended solids, but ran for twenty-three days, or rather more than twice as long as No. 1, before flooding.

These beds were much more easily cleaned than the effluent settling tanks, as the top layer of the material, with all the clogging matter, was skimmed off to the depth of 1 inch and replaced with new material. The material removed, if spread out to dry and left for some time, could be used again, though washing would have been necessary to obtain the best results.

Such beds should also be much more cheaply constructed than settling tanks. The weak point in this method of removing effluent suspended matter lies in the renewal of the upper layer of material, or in the labour involved in washing that already used. This can, however, be set against the emptying of the settling tanks, which would in many cases involve pumping, as the tanks must necessarily lie at a level below that of the filter floors.

SAND FILTER.

The filtering material was placed in a cemented concrete tank, sunk below the ground level. The tank was 24 feet long by 14 feet wide, with a bottom sloping to the outlet valve, 4 feet 6 inches below the surface of the sand. The floor of the tank was covered with perforated aerating tiles, which formed a false bottom on which the filtering material rested. This consisted of a layer of ballast, 1 foot in depth, covered with 3 feet of Leighton Buzzard sand. The total depth of material was thus 4 feet, giving a content of 50 cube yards.

The distribution of the settled effluent on to the surface of the sand was effected by a system of fixed iron pipes, laid on the surface and fed with effluent in intermittent flushes of 60 gallons.

The outlet from one pair of effluent settling tanks was connected to a shallow wooden tank, placed on the ground at the inlet end of the filter. A plug valve in the bottom of this tank allowed the effluent to flow into the distributing pipes. When the tank filled to the proper level, a small overflow pipe discharged into a bucket suspended beneath it. This bucket and the plug valve were connected by a lever, so that when the former filled, its weight raised the plug, discharging the contents of the tank through the distributor. A small hole in the bucket allowed it to empty at such a rate that the plug returned to its seating when the tank had completely discharged.

This automatic flushing arrangement gave a very good distribution, so long as the holes in the pipes were unchoked by suspended matter. The holes were originally made rather small, $\frac{1}{16}$ to $\frac{1}{8}$ inch, with the idea of keeping a better head of water in the pipes, and so improving the distribution; but some of the holes at the further end of the distributor were afterwards enlarged, as they were most liable to choke in this way. In any case, very little attention was required to keep this part of the installation in order.

The filter began working on March 2nd, 1906, at the rate of 60 gallons per cube yard per twenty-four hours. From the first the sand filter effluent was far superior to the settled effluent flowing on to it. For the first fourteen days the mere straining out of the suspended matter accounted for this, as, on March 10th, samples showed no reduction of the ammoniacal nitrogen or increase of oxidised nitrogen, compared with the settled effluent; but the effluent was very clear and bright, with a mere trace of suspended matter. It was, in fact, almost identical with the effluent flowing into the flushing tank, after the latter had been filtered through paper.

On March 16th the sand filter was stopped for one week, to mature more rapidly. The dried up deposited matter was removed by lightly raking the surface. Hardly any of the sand adhered to the deposit. On March 23rd the rate of working was increased to 120 gallons per cube yard, *i.e.*, the same rate as that at which the effluent had just passed through the clinker filters. This rate was maintained practically constant during the rest of the year's working.

On March 27th a sample of sand filter effluent, No. 99, diluted with two volumes of tap-water, was incubated for five days at 18° C. It took up only 22 per cent. of the dissolved oxygen available, equal to 0·56 part per 100,000 of undiluted effluent. The settled effluent flowing on to the sand filter, when diluted with three volumes of tap-water and incubated for five days, exhausted all the available oxygen, equal to 2·97 parts per 100,000 of undiluted effluent. The settled effluent was of poor quality at the time, owing to the trouble caused by the growth, principally in the effluent from precipitation liquor.

The following Table shows the improvement effected by the sand filtration under these conditions :—

——	Settled effluent.	Sand filter effluent.
Oxygen absorbed *at once* at 27° C. - - - - - -	0·77	0·16
" " *in 4 hours* at 27° C. - - - - -	2·42	1·05
Dissolved Oxygen taken up *in 24 hours* at 18°C. - -	0·82	—
" " " *in 5 days at* 18°C. - - -	2·97 (at least).	0·56
Suspended solids - - - - - - - - - -	2·1	Trace.
Solids by centrifuge (volumes) - - - - - -	14	3

The much greater reduction in dissolved oxygen taken up from tap water, compared with the reduction in oxygen absorbed from permanganate, is probably due : (1) to the relative freedom of the sand filter effluent from suspended matter ; (2) to the great reduction in the number of bacteria.* The latter cause has naturally greatest effect in the twenty-four hours' estimations of dissolved oxygen absorption.

During April, the sand filter matured considerably, so that apart from the almost complete removal of suspended matter, the effluent showed a marked reduction in ammoniacal nitrogen and a corresponding increase in oxidised nitrogen.

On April 21st, the nitric and nitrous nitrogen in the settled effluent amounted to 2·2 parts, and in the corresponding sand-filter effluent to 4·0 parts per 100,000.

The filters were all rested for a week from May 2nd, when the surface sand was cleaned by raking off the dried deposit.

On starting again, the first runnings from the filter were opalescent and contained an appreciable amount of suspended matter, about 2 parts per 100,000. This quickly washed out, leaving the effluent sparklingly bright, with a faint brown tint. Nitrification was exceedingly active, the effluent containing over 5 parts of oxidised nitrogen when the effluent from the stronger day sewage was passing through the filter. The interval between the stoppages necessary for cleaning the surface varied according to the amount of suspended matter in the settled effluent. With an average of 4 parts of solid, the surface would be ponded over completely about fourteen days after cleaning; while, with 2 parts, no attention was required for nearly five weeks. As soon as the surface was entirely ponded, the quality of the effluent deteriorated greatly, and in the hot weather there was hardly any dissolved oxygen in the samples. The temperature of the effluent ponded on the filter on June 22nd was 26°C. at twelve noon (fine summer day; shade temperature 82°F).

The sand filter continued working, without other rest than the cleaning of the surface made compulsory, until September 6th, when the surface had ponded over, notwithstanding its apparent cleanness as regards deposited solids. Since August 28th the filter had been taking the combined settled effluent from the filters treating settled sewage and precipitation liquor. This combined effluent was then at its best, containing 1·5 to 2·0 parts of suspended matter. It was distributed to the sand filter at the slightly increased rate of 160 gallons per cube yard per day, this being the mean rate at which the effluent had passed through the clinker filters previously. The ponding mentioned above was almost certainly not caused by the increase from 120 to 160 gallon rate. This only served to accentuate the fact previously noted, viz., that some clogging of the sand, other than the merely superficial, had slowly been in progress. The quality of the effluent at the increased rate of working showed no falling off until the flow had to be stopped, to prevent the flooding of the containing tank.

The filter was rested for four weeks, during which the upper 4 inches of sand was turned over two or three times. On October 4th the settled effluent was turned on to the sand again, at first at 80 gallons per cube yard. This drained quite freely through the bed between the flushes from the distributor, washing out a considerable amount of suspended matter during the first twenty-four hours. The rate was then increased to 160 gallons, and on October 9th the sample of effluent incubated for five days at 18° took up only 0·10 of dissolved oxygen per 100,000.

* *See* Part V., Dr. Houston's Report, p. 213.

The filter ran for fourteen days before cleaning was necessary. This was about its normal time with the amount of suspended matter then present in the settled effluent. On October 20th the flow to the filter was stopped, the effluent being all required for treatment in the sterilisation tank.

As far as could be judged, the freshly cleaned filter would not pass as much effluent through it, before ponding, as it had done in the spring, when the sand was perfectly new. The month's rest in September had, however, improved its condition very appreciably. It is evident that, in working on the large scale, at least two filters would be required, so that one might be periodically rested.

The samples of sand filter effluent were all single samples, taken immediately after the fourth or middle sample of the four hours average sets, which were drawn every eight days. Thus, if the average samples were taken from 8 a.m. to 11.30 a.m., the sand filter effluent was drawn at 9.30 a.m. They are, therefore, representative of the sewage under all conditions during the time the experiment lasted.

Average Figures of Analysis for Sand Filter Effluent, March 27th to October 17th, 1906.

Parts per 100,000.	Average.	Number of Estimations.
Oxygen absorbed at 27°C. at once	0·36	21
" " " in 4 hours	1·15	21
Dissolved Oxygen taken up in 24 hours at 18°C.	0·08	16
" " " 5 days " "	0·36	18
Incubator Test (by smell)	All passed	21

The bacteriological results obtained in these experiments, and in the experiment on the sterilisation of the filter effluent by chloros (sodium hypochlorite), are given in Dr. Houston's Report.

GENERAL CONCLUSIONS.

The results of the year's work may be summarised as follows :—

(1) *Reduction of Suspended Matter.*

The reduction of suspended solids in the sewage was practically the same for the continuous flow settlement and the septic tank processes, as shown by the average figures for the year. The septic tank liquor contained much more suspended matter than the settled sewage in the hot summer weather, but during the rest of the year it contained rather less.

Precipitation with continuous flow gave a liquor which contained two-thirds the suspended matter of the other tank liquors and which was about three-quarters as strong, organically ; it was thus capable of filtration at nearly twice the rate at which the other tank liquors yielded an effluent of similar purity.

(2) *Sludge Production.*

The weights of *wet* sludge produced by the three processes are in the ratio :—

Settled Sewage.		Precipitation.		Septic Tank.
3	:	5	:	1

The corresponding ratio for *dry* sludge matter is :—

2	:	2·5	:	1

The septic tank process produces, therefore, by far the least sludge.

(3) *Purification of Tank Liquors by Coarse Percolating Filters.*

The average figures for the year, given by the effluents from the filters treating settled sewage and septic tank liquor, were very similar. The effluent from the filter treating septic tank liquor was not quite so well purified organically as the effluent from the filter treating settled sewage, but it contained more oxidised nitrogen. The discharge of suspended solids from the septic tank in the hot weather caused a corresponding increase of solids in the filter effluent. Under these conditions the effluent solids were not well oxidised, but the effluent as a whole was never putrescible.

The effluent from the filter treating precipitation liquor was the best of the three effluents for the greater part of the year. But during the period of four weeks, when the fungoid growth was choking the filter, it was distinctly the worst. When filtered at 211 gallons per cube yard, this effluent, judged by its analysis, was equal in purity to the effluent from the filters treating settled sewage and septic liquor at 120 gallons per cube yard. The larger volume of precipitation liquor, however, which can be purified by a cube yard of filter, is a result of the work already done on the sewage by the tank treatment. It does not indicate that a filter is more efficient when treating this kind of tank liquor.

(4) *Settlement of Suspended Solids in Effluents.*

The suspended solids in the filter effluents were reduced by 50 per cent. in from one to two hours' continuous flow settlement. Frequent removal of the deposit in the settling tank is advisable in warm weather.

When the suspended solids in the filter effluent are especially liable to fermentation, filtration through shallow beds of fine material is a better method of removing them.

(5) *Sand Filtration.*

By passing the settled effluent through the sand filter, practically all the suspended matter was removed and there was a great improvement chemically. The filter, therefore, did not act as a mere strainer, but effected a further bacterial oxidation of the effluent.

(6) *Nuisance.*

The settled sewage process caused very little nuisance from smell, either in sludging or in distribution upon the filter.

The precipitation process caused no appreciable niusance in sludging and practically no nuisance in distribution.

The septic tank process, on the other hand, gave rise to considerable smell in sludging and to very great nuisance in distribution during warm weather.

EXPERIMENT ON THE TREATMENT OF SETTLED SEWAGE AND SEPTIC TANK LIQUOR ON THE SAME FILTER.

In his evidence before the Commission on May 12th, 1905 (answer to Question 22780), Dr. G. J. Fowler expressed the opinion that only a portion of the sewage which arrives at an outfall works in times of storm should be passed through a septic tank. Amongst other reasons for this view he stated " that the tank liquor tends to become merely settled sewage, and to remain so for some time after the increased flow, so that the results from the subsequent filtration deteriorate somewhat."* Some results from the Manchester contact beds given subsequently by Dr. Fowler certainly seemed to bear out this conclusion.

As this point is one of considerable practical importance, it seemed useful to make some direct experiments at Dorking by interchanging septic tank liquor and settled sewage on a coarse percolating filter.

Two experiments were carried out as follows :—

Experiment I.

The percolating filter of coarse clinker, which had been treating septic tank liquor at the rate of 120 gallons per cube yard per day, was used for these experiments. On June 20th, 1907, four samples of septic tank liquor were drawn, one every half-hour from 3 p.m. to 4.30 p.m., and mixed in equal quantities. Four samples of the filter effluent were drawn and mixed in the same way. As soon as the 4.30 samples had been taken, sewage settled by 10 hours continuous flow in the small tank alongside the septic tank, was turned on to the sprinkler without stopping it.

The septic liquor was then shut off. The settled sewage was delivered to the filter at the same rate of flow as the septic tank liquor, viz., 120 gallons per cubic yard. From 5 p.m. to 6.30 p.m. four half-hourly samples of settled sewage were drawn, and four of the corresponding effluent. These were averaged as before.

The figures of analysis given by the four average samples are tabulated below :—

——	Septic Tank Liquor.	Effluent from filter treating septic tank liquor.		Settled Sewage.	Effluent from filter treating settled sewage.	
		Whole effluent.	Paper-filtered.		Whole effluent.	Paper-filtered.
Ammoniacal Nitrogen	5·90	—	0·76	6·94	—	0·91
Albuminoid Nitrogen	1·00	—	0·20	0·78	—	0·14
Nitrous Nitrogen	none	—	0·04	none	—	0·05
Nitric Nitrogen	none	—	2·7	none	—	2·5
" Oxygen absorbed " in four hours	8·15	3·46	1·56	6·99	3·18	1·43
Incubator test (by smell)	—	Passed	Sweet earthy	—	Passed	Sweet earthy
{ Solids by centrifuge (vols.)	56	100	—	47	106	—
{ Equivalent to suspended solids (approx.)	9·0	6·6	—	8·0	7·0	—
Calculated strength	88·5	—	– 2·9	83·9	—	– 2·1

It will be noticed that the settled sewage was rather stronger in ammoniacal nitrogen than the septic tank liquor, but it absorbed less oxygen from permanganate in 4 hours, so that the two liquors are of approximately equal strength. Both the corresponding effluents were slightly opalescent and smelt earthy, but that from the septic tank liquor was rather browner in tint than the other.

* Fifth Report of the Commission, App. I., p. 372.

From the above figures it is evident that the change from septic tank liquor to settled sewage had not upset the oxidising power of the filter. The calculated strengths of the effluents, without suspended solids and allowing credit for nitrate, show that the filter effected practically equal purification with both types of liquor.

Experiment 2.

To decide further whether the two tank liquors were perfectly interchangeable, a more severe test was then carried out. After the filter had been working normally with septic tank liquor for two weeks, samples of the liquor and corresponding effluent were drawn at 4 p.m. on July 8th. Settled sewage from the freshly filled tank was then substituted and two more samples were drawn at 5 p.m. The filter was fed with settled sewage for 24 hours, when septic tank liquor was again turned on and two samples drawn at 5 p.m. This method of working the filters alternately with septic tank liquor and settled sewage was continued for a week, the change being made at 4 p.m. each day and two samples taken one hour later.

Figures of analysis for these 16 samples are given below.

Septic Tank Liquor.		Effluent from Septic Tank Liquor.		
Oxygen absorbed in four hours.	Solids by Centrifuge. Vols.	Oxidised Nitrogen.	Oxygen absorbed in four hours.	Solids by Centrifuge. Vols.
8·15	76	2·65	2·61	82
8 17	76	2·65	1·89	70
9·06	99	3·08	2·75	70
8·14	87	3·05	2·85	82
Average 8·38	85	2·86	2·53	76

Settled Sewage.		Effluent from Settled Sewage.		
7 66	64	2·76	2·05	82
10·25	52	2·75	3·62	70
9·35	64	3·10	3·32	77
8·70	64	3·05	2·80	77
Average - 9·06	61	2·92	2·86	77

All the effluents kept sweet on incubation for 5 days at 27° C. The figures for " oxygen absorbed " in 4 hours show that with septic tank liquor the reduction effected by the filter was 70 per cent., while with settled sewage the reduction was 68 per cent. As the latter was slightly the stronger of the two tank liquors, the purifications are again alike, practically speaking.

This second experiment thus confirmed the results obtained in the first, and proved that settled sewage can be substituted for highly septic tank liquor without causing any deterioration in the effluent produced by a percolating filter, which has been matured and is being normally worked with septic tank liquor.

In both the above experiments the septic tank liquor and settled sewage were rather above average strength, while the former was typically septic, with considerable smell of sulphides. Since these strong liquids can safely be interchanged, it may be assumed with some confidence that storm water passing through a septic tank would have no appreciable effect on a filter.

PART II.—THE PRECIPITATION OF SEPTIC TANK LIQUOR BY A SMALL QUANTITY OF LIME.

During the summer of 1906 the distribution of septic tank liquor on to the percolating filter at Dorking gave rise to considerable nuisance in the neighbourhood of the sprinkler. Experiment showed that the smell could be very greatly reduced by the addition of an alkaline solution to the liquor before it passed to the sprinkler. From 5 to 10 grains per gallon of sodium carbonate (ordinary washing soda) were required to remove all smell of volatile sulphides. The filter effluent was not adversely affected during the two or three weeks that the experiment lasted. The cost at Dorking of adding sodium carbonate would be from 30s. to 60s. per 1,000,000 gallons, which prohibits the use of this method on the large scale. For occasional use in very hot weather, or with specially offensive liquor, the process might be useful.

Before the above experiment was made, Dr. McGowan had suggested that a small quantity of lime added to the septic tank liquor, and followed by a short settlement, might reduce the amount of suspended matter which leaves the septic tank. This suggestion led to the experiments, which are described below, being carried out for the Commission at Dorking. It ought to be mentioned that it has been the practice at Blackburn for several years to add lime to the septic tank liquor at the rate of about 1 grain per gallon, with the idea of assisting nitrification on the filters.

The lack of control over the solids passing from septic tanks to the filters or contact beds is one of the weak points in the septic tank process, as usually carried out. Precipitation with lime prevents excessive suspended matter from reaching the filters and at the same time removes the nuisance from smell in distribution. A third advantage, not originally anticipated, is the increased quantity of limed septic liquor which can be passed through the filter, as compared with unlimed liquor, and yet yield a satisfactory effluent.

Preliminary Experiment.

The experimental septic tank has a capacity of 5,500 gallons, while the only small tank available for the settlement after the addition of the lime holds 2,087 gallons. The septic tank was worked at its normal rate of 24 hours continuous flow settlement, which gave 10 hours further settlement in the small tank, or 34 hours in all. This is much longer than is necessary.

A series of 4-hours average samples, drawn half hourly every day from 22nd to 28th May, 1907, gave the following analytical results. 2·5 grains of lime were added to each gallon of septic tank liquor.

Parts per 100,000.	Screened Sewage.	Septic Tank Liquor.	Limed Septic Liquor.
"Oxygen absorbed" in 4 hours - - - -	13·60	8·02	6·61
Suspended solids - -	19·6	7·5	5·7
Volatile matter in solids -	15·2	6·0	4·0
Solids by centrifuge (vols.)-	163	40	26

While the untreated septic liquor had a strong and very objectionable smell of sulphides, the limed liquor passing to the filter smelt like freshly settled sewage.

Contrary to expectation, no difficulty was experienced in keeping the sludge down in the second tank. In fact, the tank has been run for 14 days without the sludge rising to the surface. It is advisable, however, to clean the small tank out once a week, or more frequently in very hot weather.

Owing to the lack of a suitable mixer, the lime, as milk of lime, could only be added very irregularly, particularly at night. It should be well mixed with the septic liquor at the inlet to the small tank. In spite of practical difficulties the results were encouraging, as far as they went, especially as the limed septic liquor when passed through the coarse percolating filter at 150 gallons per cube yard gave an unusually good effluent.

Experiment No 1.

It was accordingly decided to increase the flow through the tanks to 7,600 gallons per 24 hours, giving 17 hours settlement in the septic tank and 7 hours in the precipitation tank, or 24 hours in all. The lime was added at the same rate as before, viz. 2·5 grains per gallon, but now much more uniformly, by means of an automatic mixer devised by Mr. A. F. Girvan. This was driven by a water-wheel running day and night.

The experiment continued from October 14th, 1907, when the septic tank had been running 9 months since the last cleaning, to June 15th, 1908, when the tank was again cleaned. 19 sets of 8-hours average samples were examined during this time. They were usually drawn at intervals of 15 days. The results are given in the following table.

Average figures of analysis for septic tank liquor and limed septic liquor. Eight hours average samples drawn between October 14th, 1907, and May 29th, 1908.

Parts per 100,000.	Septic Tank Liquor.	Limed Septic Liquor.	Number of Estimations.
Ammoniacal nitrogen -	5·49	5·25	9
Albuminoid nitrogen -	0·76	0·67	9
Total organic nitrogen -	1·23	1·13	8
Nitrous nitrogen - -	0·00	0·00	9
Nitric nitrogen - -	0·00	0·00	9
"Oxygen absorbed" at 27° C. at once - -	2·09	1·63	19
"Oxygen absorbed" at 27° C. in 4 hours	6·73	5·76	19
Dissolved oxygen taken up at 18° C. in 5 days-	24·53	23·69	5
Suspended solids -	8·91	7·40	19
Volatile matter in solids	7·23	4·80	19
Solids by centrifuge (vols.)	59	41	19
Ratio of suspended solids to centrifuge solids -	1 : 6·6	1 : 5·5	—
Chlorine - - -	7·54	7·54	9
Calculated "strength" -	76	68·3	—

There is an appreciable reduction in the "oxygen absorbed" figures after the precipitation with lime. This follows from the reduction of the volatile or organic suspended solids from 7·2 to 4·8 parts per 100,000. At the same time the actual figure for suspended solids, 7·4, is not so good as in the preliminary experiment. The increased rate of flow was no doubt responsible for this.

Sludge production.

This is one of the most important questions in considering the feasibility of the process on a large scale. If the total sludge production from the septic tank and the lime precipitation tank together is much below that from direct precipitation of the sewage, while the final liquor can be filtered as rapidly as septic tank liquor untreated, there is an evident advantage in the absence of smell in distribution and in the smaller amount of solids going to choke contact beds or having to be dealt with in the percolating filter effluent.

In 30 weeks 1,593,000 gallons of septic tank liquor passed through the smaller tank. This left 19·00 cubic yards of very wet sludge, containing 2·81 per cent. of dry solid matter. The quantity of sludge to be removed each week was too small to allow all the supernatant liquor to be run off, since the settled sludge lay below the level of the floating arm. At least one-third of the volume measured was water, which on the large scale could be run off. The sludge was not more offensive than that from freshly settled sewage.

A comparison of the amount of sludge produced by this process with that yielded by the three other methods of tank treatment can now be given.

Process.	Tons of *dry* Sludge Matter per 1,000,000 gallons of Sewage.	Ratio.
Septic tank (alone) - -	0·52	1·0
Septic tank and lime tank -	0·77	1·5
Simple settlement without chemicals - - - -	1·07	2·1
Direct precipitation with chemicals - - -	1·31	2·5

These figures are arrived at by taking the results of the experiments of 1905–1906 for the settled sewage and precipitation sludges, while the figures for the two septic tank processes are for 1907–1908.

The production of sludge is thus increased by 50 per cent., if the lime tank is added to the usual septic tank.

For the practical success of the process, apart from the question of smell, the cost of disposing of the extra sludge must be more than balanced by the saving in the cost of filtration, which the limed septic liquor permits.

Filtration of the Limed Septic Liquor.

The limed septic liquor was filtered through the coarse percolating filter (2 to 4 inch clinker), which had previously treated ordinary septic tank liquor. This filter was 5ft. 7in. deep.

From October 14th to December 16th, 1907, the rate of filtration was 150 gallons per cube yard. Seven sets of 8-hours average samples of filter effluent were drawn at intervals of 8 days. They gave the following figures of analysis—

Oxidised nitrogen	2·60
"Oxygen absorbed" at once	0·61
" " in 4 hours	1·83
Solids by Centrifuge (vols.)	66
Equivalent to suspended solids	3·5 approx.
Incubator test (by smell)	All passed.

The effluent was bright, with a brownish tinge. It contained from 3 to 4 parts of suspended solids and usually had a faint earthy smell.

On December 16th the rate of filtration was increased to 211 gallons per cube yard. This was continued till June 15th, 1908, during which period 12 sets of 8-hours samples of filter effluent were examined. The results are given in the following table.

Average figures of analysis for effluent from coarse percolating filter treating limed septic liquor at 211 gallons per cubic yard. Samples drawn between December 19th, 1907, and May 29th, 1908.

Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal nitrogen	2·01	9
Albuminoid nitrogen	0·29	9
Total organic nitrogen	0·63	7
Nitrous nitrogen	0·08	12
Nitric nitrogen	1·64	12
"Oxygen absorbed" at 27° C. at once	0·65	12
"Oxygen absorbed" at 27° C. in 4 hours	2·30	12
"Oxygen absorbed" at 27° C. in 4 hours (paper filtered)	1·25	8
Dissolved oxygen taken up in 48 hours at 18° C.	1·53	9
Dissolved oxygen taken up in 5 days at 18° C.	4·45	8
Dissolved oxygen taken by paper filtered sample in 5 days at 18° C.	1·05	7
Suspended solids	6·3	9
Volatile matter in solids	4·7	9
Solids by centrifuge (vols.)	81	10
Chlorine	6·95	8
Incubator test (by smell)	All passed.	12

The above figures show that the effluent was of fair quality, non-putrescible, and on the safe side of the provisional standard suggested by the Commission in their Fifth Report for absorption of dissolved oxygen in 5 days by the paper filtered sample. The suspended solids, however, require to be reduced either by settlement or by fine filtration.

The oxidisability of the whole effluent (including suspended solids and giving credit for the nitrate present), as calculated by Dr. McGowan and Mr. Frye's formula, is 16·4. The strength of the limed liquor being 68·3, there is a purification of 76%, with 10,960 "units of purification" per cube yard. The calculated oxidisability of the liquid portion of the effluent is 5·5, showing 92% purification.

The "oxygen absorbed" in 4 hours by the whole effluent, *i.e.*, including the suspended solids, shows a reduction of 59 per cent. on the limed liquor figure.

The effluent was brown tinted, but bright, with an earthy smell. The suspended solids were well defined and settled easily.

The surface of the clinker was covered during the winter with a coating of grey growth (cladothrix dichotoma), but no appreciable ponding resulted.

Experiment No. 2.

On June 22nd, 1908, the septic tank was re-started after removing the greater part of the sludge, but 34 cubic feet of sludge were left in the tank for the purpose of inoculation. The next day the surface was covered with a thin scum, which became permanent. The weather was normal for the season, the shade temperature varying from 56° to 70° F. The tank liquor already had a distinctly "septic" smell.

The rapidity with which the tank matured was in marked contrast with the time taken in the experiment of 1905-1906. The tank was then started quite clean in the late autumn, and no permanent scum formed until the following March. The rate of flow, moreover, was then 24 hours continuous flow settlement, while in the present experiment it was 17 hours. The effects of inoculation and temperature on the working of septic tanks are well known, but the remarkable difference in these respects shown by the two experiments seemed worth noting.

In order to see if the addition of more lime to the septic tank liquor would permit of a further increase in the rate of filtration, 3·5 grains of lime were added per gallon of liquor, instead of the 2·5 grains in experiment No. 1. The rate of flow through the tanks was the same as before, viz.—17 and 7 hours continuous flow settlement.

After 4 weeks' working the rate of flow through the tanks was increased slightly, so as to produce a larger volume of limed liquor for filtration. The rate of flow was now 15·5 hours in the septic tank and 6·5 hours in the lime tank, or 22 hours in all. This rate of working, which continued in use up to February 18th, 1909, has given consistently good results. The untreated septic tank liquor had always a strong and very objectionable smell of sulphide, while the limed septic liquor going on to the filter had usually a stale sewage smell, giving rise to no nuisance in distribution. The weather was exceptionally fine and warm during the summer months. Under similar conditions a much smaller volume of untreated septic tank liquor, after 24 hours settlement, gave rise to considerable nuisance in 1906.

Fifteen sets of 8 hours' average samples of the two tank liquors were drawn at interval of 8 days. They gave the following figures of analyses.

Average figures of analysis for septic tank liquor and limed septic liquor. Samples drawn between June 28th and November 17th, 1908.

Parts per 100,000.	Septic Tank Liquor.	Limed Septic Liquor.	Number of Estimations.
Ammoniacal nitrogen	5·23	4·78	15
Albuminoid nitrogen	0·67	0·50	15
Total organic nitrogen	1·43	1·13	15
Nitrous nitrogen	0·00	0·00	15
Nitric nitrogen	0·00	0·00	15
Oxygen absorbed at once	2·11	1·43	15
" " in 4 hrs.	6·61	5·37	15
Suspended solids	11·20	8·62	15
Volatile matter in solids	8·92	5·61	15
Solids by centrifuge (vols.)	76	34	14
Ratio of suspended solids to centrifuge solids	1 : 6·8	1 : 3·9	—
Chlorine	9·51	9·02	14
Calculated "strength"	72·9	61·5	—

Filtration of Limed Septic Liquor.

The limed liquor was filtered at the rate of 275 gallons per cube yard for the first four weeks, during which time 3 sets of 8 hours average samples were drawn. The effluents were all very satisfactory and gave the following figures.

AVERAGE FIGURES OF ANALYSIS FOR EFFLUENT FROM LIMED SEPTIC LIQUOR FILTERED AT 275 GALLONS PER CUBE YARD. SAMPLES DRAWN BETWEEN JUNE 28TH AND JULY 21ST, 1908.

Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal nitrogen	1·34	3
Albuminoid nitrogen	0·15	3
Total organic nitrogen	0·47	2
Nitrous nitrogen	0·12	3
Nitric nitrogen	1·96	3
"Oxygen absorbed" at 27° C. at once	0·59	3
"Oxygen absorbed" at 27° C. in 4 hours	1·78	3
"Oxygen absorbed" in 4 hours at 27° C. (paper filtered)	1·35	3
Dissolved oxygen taken up in 48 hours at 18° C.	0·87	3
Dissolved oxygen taken up in 5 days at 18° C.	2·74	3
Dissolved oxygen taken up in 5 days at 18° C. (paper filtered)	0·69	3
Suspended solids	2 57	3
Volatile matter in solids	1·77	3
Solids by centrifuge (vols.)	47	3
Chlorine	8·87	3
Incubator test (by smell)	All passed	3

These effluents were all bright looking, with a moderate amount of well defined solid, which settled quickly. They may be classed as very fair effluents.

The calculated oxidisability of the whole effluent, including suspended solids and giving credit for the nitrate present, is 5·8. The percentage purification is 90, with 15,130 units of purification per cube yard. The calculated oxidisability of the paper filtered effluent is 1·2, showing 98 per cent. purification.

As this rate of filtration also gave such satisfactory results, it was decided to further raise the flow to 350 gallons per cube yard, with the idea of seeing if this very high rate of working would still result in a non-putrescible effluent. From July 27th, 1908, to February 18th, 1909, the filter was worked at this rate of flow. Twelve sets of 8 hours' average samples were drawn, so as to correspond with the limed septic liquor going on to the filter. They gave the following figures of analysis.

AVERAGE FIGURES OF ANALYSIS FOR EFFLUENT FROM LIMED SEPTIC LIQUOR FILTERED AT 350 GALLONS PER CUBE YARD. SAMPLES DRAWN FROM JULY 28TH TO NOVEMBER 17TH, 1908.

Parts per 100,000.	Average.	Number of Estimations.
Ammoniacal nitrogen	2·33	12
Albuminoid nitrogen	0·30	12
Total organic nitrogen	0·60	9
Nitrous nitrogen	0·15	12
Nitric nitrogen	1·14	12
"Oxygen absorbed" at 27° C. at once	0·68	12
"Oxygen absorbed" at 27° C. in 4 hours	2.44	12
"Oxygen absorbed" at 27° C. in 4 hours (paper filtered)	1·20	12
Dissolved oxygen taken up in 48 hours at 18° C.	2·24	12
Dissolved oxygen taken up in 5 days at 18° C.	6·60	12
Dissolved oxygen taken up in 5 days at 18° C. (paper filtered)	0·59	12
Suspended solids	5·28	12
Volatile matter in solids	4·19	12
Solids by centrifuge	84	12
Chlorine	8·61	11
Incubator test (by smell)	All passed	12

While the oxidised nitrogen has fallen off considerably and the unoxidised nitrogen has risen, there is still sufficient nitrate in the effluent to keep it sweet on incubation. The suspended solids now take up a large amount of dissolved oxygen, although their actual quantity is slightly less than shown in the table on page 197 for the effluent filtered at 211 gallons per cube yard. On the other hand, the paper-filtered samples took up surprisingly little oxygen, the average figure being well below the provisional standard of 1·5 parts per 100,000 in 5 days. These results show that the increased rate of flow has affected to some extent the oxidation of the ammonia and of the organic matter of the suspended solids, but has not appreciably affected the oxidation of the dissolved organic matter.

The effluents were slightly brown in colour, but usually bright, with the suspended matter well defined and easily settled. They smelt either earthy or fishy-earthy when drawn.

The calculated oxidisability of the whole effluent, including suspended solids and giving credit for the nitrate, is now 18·1, showing 71 per cent. purification on the limed septic liquor, with 15,175 units of purification—a very high figure. The calculated oxidisability of the liquid portion of the effluent is 8·4, showing 86 per cent. purification. The reduction on the 4 hours "oxygen absorbed" figure for the whole effluent is 55 per cent.

Between November 24th, 1908, and February 14th, 1909, ten further sets of average samples were drawn, at the same rate of flow. During the last seven weeks of this period the weather was exceptionally cold; the mean temperature for January and February was only 37° F., as recorded by a sheltered thermometer hung on the filter wall. Even under these adverse climatic conditions the filter worked well. Every sample passed the incubator test; the worst, when paper filtered, took up 0·97 part of dissolved oxygen per 100,000 in 5 days, i.e., it was well within the provisional standard. The average analysis of the effluent was identical, practically speaking, with that given in the table above. The purification was the same, viz. 71 per cent., and 15,340 units per cube yard were effected by the filter.

The analysis of this effluent shows that the rate of 350 gallons per cube yard per day is somewhere near the working limit for this strength of limed septic liquor, passing through a matured percolating filter of 2–4 inch clinker. An increase to 400 gallons would almost certainly result in putrescible effluents at those times when the liquor is at its maximum strength for the day.

It is not, of course, suggested that on the large scale filters should be designed to work at so high a rate of flow, but the results of these experiments show that, with a sewage of average strength (100), limed septic liquor may be efficiently filtered through coarse material at a rate of 150 to 200 gallons per cube yard per day. This would ensure a factor of safety sufficient to cover all ordinary variations in the strength of the liquor or in the working efficiency of the filters.

Experiment No. 3.

The preceding experiment showed that limed septic tank liquor could be filtered at a rate of 350 gallons per cube yard through a coarse percolating filter in the coldest weather, and yet yield an effluent which, including its suspended solids, was uniformly non-putrescible, while the paper filtered effluent took up very little dissolved oxygen in 5 days. The next step was to see how untreated septic tank liquor would behave when filtered at the same rate through the same filter. The addition of lime was therefore stopped, on February 18th, 1909, and septic tank liquor (22 hours' continuous flow settlement) was passed through the filter at the rate of 350 gallons per cube yard. Although the weather was cool, a distinct nuisance from smell was now noticeable around the filter.

From previous experience with lower rates of flow, it was expected that the effluent would be a bad one. The figures given below show that this was the case. The nitrification was very poor in all the samples, while the first sample, drawn at 4 a.m. from the weakest liquor, was the only one that passed the incubator test.

On March 16th a chance sample of effluent drawn at noon contained only 2·7 c.c. of dissolved oxygen per litre and had rather a suspicious smell.

It is evident that septic tank liquor of rather below average strength cannot be filtered successfully at 350 gallons per cube yard, while with limed septic tank liquor this high rate can be maintained even under adverse climatic conditions.

It should be noted that while the limed liquor gave little trouble from stoppage of the jets in the sprinkler arms, untreated septic liquor required frequent attention with this type of distributor. The irregular distribution caused by these temporary stoppages slightly reduces the contact during percolation and to this extent handicaps the septic liquor in comparison with the limed liquor.

AVERAGE FIGURES OF ANALYSIS FOR SEPTIC TANK LIQUOR AND EFFLUENT FILTERED AT 350 GALLONS PER CUBE YARD.

Five sets of 8-hours average samples drawn between February 23rd and March 28th, 1909.

Parts per 100,000.	Septic Tank Liquor.	Effluent from Septic Tank Liquor.
Ammoniacal nitrogen	4·90	3·63
Albuminoid nitrogen	0·64	0·46
Total organic Nitrogen	1·40	0·98
Nitrous nitrogen	0·00	0·09
Nitric nitrogen	0·00	0·33
"Oxygen absorbed" at 27° C. at once	1·75	1·22
"Oxygen absorbed" at 27° C. in 4 hours	6·55	4·52
"Oxygen absorbed" at 27° C. in 4 hours (paper filtered)	—	2·03
Dissolved oxygen taken up in 48 hours	—	3·22
Dissolved oxygen taken up in 5 days	—	12·70
Dissolved oxygen taken up in 5 days (paper filtered); all three at 18° C.	—	1·60
Suspended solids	9·38	9·24
Volatile matter in solids	8·04	7·72
Solids by centrifuge (vols.)	51	148
Chlorine	7·23	7·41
Incubator test (by smell)	—	1 passed 4 failed
Calculated strength	70·9	35·2

The figures given above show that the filter was unable to produce an effluent from unlimed septic tank liquor, when filtered at the rate of 350 gallons per cube yard, which would conform to the provisional standard suggested by the Commission, and this although the septic liquor was distinctly below its average strength at the time these samples were drawn. The liquor was, however, typically "septic," with a slight smell of sulphides, and it contained a considerable amount of suspended solids. The calculated oxidisability of the whole effluent, including suspended solids, is 35·2, showing only 50 per cent. purification on the septic tank liquor, as compared with the 71 per cent. effected on the limed septic liquor at the same rate of flow. The units of purification are now 12,500, while with limed liquor over 15,000 units were effected per cube yard of filter. The liquid portion of the effluent is also unsatisfactory, as judged both by the 4 hours "oxygen absorbed" test and by the "dissolved oxygen taken up in 5 days." The purification effected on the liquid portion of the effluent, as calculated on the atmospheric oxygen used up, is 75 per cent., compared with 86 per cent. when limed septic liquor was in use. It is evident, then, that the addition of lime to the septic liquor, besides greatly reducing the nuisance from smell, enables a larger amount of tank liquor to be efficiently purified by the filter.

SUMMARY.

The method of tank treatment described in this report is a compromise between the usual septic tank and precipitation processes. Its result in the case of a domestic sewage, at all events, is to produce a tank liquor which contains only a moderate amount of suspended matter and which is capable of efficient filtration, with a mimimum of smell, at a relatively high rate of flow. This is accomplished without the production of nearly so large an amount of sludge as direct precipitation involves.

A sewage of average strength (about 100) yields a septic tank liquor of strength about 80, which must be filtered at a rate of 75-100 gallons per cube yard per day on coarse percolating filters, if a perfectly satisfactory effluent is to be produced. The limed septic liquor from the same sewage would have a strength of about 67, and could be filtered at 150-200 gallons per cube yard with equally good results.

It was at first thought that the lime enabled the tank liquor to take up oxygen more readily than the untreated septic tank liquor, and that this explained the increased amount which could be purified by a cube yard of filter. Experiments were made in the laboratory to test this point, but they failed to show that the limed liquor was more amenable to oxidation than unlimed septic liquor.* It is probable, then, that the true explanation is to be found chiefly in the reduction in "strength" of the septic tank liquor by the lime treatment, and to a smaller extent in the more perfect distribution which is possible in the absence of coarse suspended matter.

The sludge production is increased by 50 per cent., as compared with the septic tank alone, but the extra sludge is less objectionable and is more easily pressed than septic tank sludge.

As far as experiment on a small scale can show, the cost of the limed septic liquor process should be considerably less than direct precipitation, including both the tank treatment and the subsequent filtration. There would be a saving in cost of chemicals and of sludge disposal, while the cost of the filters would not be increased in the same proportion. In some cases the limed septic liquor process might conceivably be cheaper than septic tanks alone. This would, however, only occur where the saving in the cost of filters more than balanced the cost of liming and of disposing of the extra sludge.

This process would seem to be well adapted to those places where economy in labour is an important consideration, but where a good effluent must be produced without the nuisance which septic tank installations are liable to cause. The conversion of existing septic tank systems to the liming process need not be a very costly undertaking.

PART III.—DEEP AND SHALLOW FILTER EXPERIMENTS.

Objects of the Experiment.

These experiments were designed to show the effect of depth of filtering medium in percolating filters constructed (a) of coarse material, (b) of very fine material.

The experiments previously carried out at Horfield and Ilford showed that with deep and shallow filters of coarse material, treating equal quantities of tank liquor per cube yard per day, there was little to choose between the resulting effluents. The small difference was usually in favour of the deep filter.†

On the other hand, Dr. G. Reid, in his experiments on the fine filters at Hanley, found that he obtained an effluent at a depth of 3 feet which was actually better in some respects than that drawn from the full depth (4½ feet) of the filter.†

In order to investigate these apparently contradictory results, the following experiments were carried out at Dorking.

Sewage Treated.

The sewage used in these experiments was almost entirely domestic and of about average strength. The figures of analysis given by 21 sets of average samples, taken from November, 1905, to November, 1906, have already been recorded on page 174.

Tank Treatment.

The sewage was precipitated with 10 grains of alumino-ferric and 5 grains of lime per gallon, followed by 10 hours continuous flow settlement. The tank was cleaned once a week, as a rule, but twice a week in hot weather. The average analysis of the precipitation liquor is given in the following Tables I. to VIII., together with the analysis of the corresponding effluents.

Construction of Filters.

The coarse material (2″–4″), used in the experiments of 1905–06, was removed from the two filters which had treated settled sewage and precipitation liquor. A vertical partition was built across each framework, so as to divide it into two semi-octagonal sections. The well-mixed clinker having been screened through a 1″ mesh, was washed in sewage and replaced in one section

* *Cf* Paper by Dr. McGowan and Mr. Girvan on the subject, this Appendix, p. 470.
† *Cf.* Fifth Report of the Commission, Appendix I, p. 759; also Fifth Report, p. 78.

of each filter. The first or shallow filter was filled to a height of 2′ 5″, the second or deep filter to 4′ 10″. A portion of the remaining coarse material was broken down to $\frac{1}{4}$–$\frac{1}{2}$″ size, well washed, and placed on the other side of each partition to a height of 1′ $2\frac{1}{2}$″ and 2′ 5″ respectively. A few pieces of coarse clinker had previously been placed on the aerating tiles to prevent the fine material falling through the slots. More of the old material was then broken down to $\frac{1}{8}$–$\frac{1}{4}$″ size, washed, and placed on top of the $\frac{1}{4}$–$\frac{1}{2}$″ clinker, so as to raise the fine sections to a level with the coarse material on the other side of the partitions.

The construction of the filters may be summarised as follows:—

Area of each filter = 6·375 square yards.

——	Material.	Depth of Material.	Size of Material.	Cubic content of filter, in yards.
Coarse Shallow Filter - -	Clinker.	2′ 5″	1″ to 4″ throughout.	5·14
Coarse Deep Filter - - -	Clinker.	4′ 10″	1″ to 4″ throughout.	10·28
Fine Shallow Filter - - -	Clinker.	2′ 5″	Top 1′ $2\frac{1}{2}$″ of $\frac{1}{8}$″ to $\frac{1}{4}$″ diam. Bottom 1′ $2\frac{1}{2}$″ of $\frac{1}{4}$″ to $\frac{1}{2}$″ diam.	5·14
Fine Deep Filter - - -	Clinker	4′ 10″	Top 2′ 5″ of $\frac{1}{8}$″ to $\frac{1}{4}$″ diam. Bottom 2′ 5″ of $\frac{1}{4}$″ to $\frac{1}{2}$″ diam.	10·28

The distribution of the precipitation liquor on to the filters was effected by two tipping troughs, which discharged intermittently into the cisterns of two rotating sprinklers, one on the shallow and one on the deep filter. These tipping troughs and sprinklers were specially made for this experiment by Mr. G. B. Kershaw, the Engineer to the Commission, so as to give a consistently uniform distribution with very varied rates of flow. Each flush of liquor contained 5 gallons. The interval between the flushes of tank liquor was 7·5 minutes in Experiment I. In the subsequent experiments this was gradually reduced, so that in Experiment VI, at 450 gallons per square yard, the interval was only 1·25 minutes. The distribution by this method was as satisfactory as it can be made with this type of sprinkler. Any device in which liquor containing suspended matter is delivered through small holes is more less objectionable, on account of the frequent attention required to clear the jets.

TABLE I.

Average Figures of Analysis for Precipitation Liquor and Effluents. Twelve Analyses.

All Filters working at the rate of 75 Gallons per Square Yard.

June 27th to September 27th, 1907.	Ammoniacal Nitrogen.	Albuminoid Nitrogen.	Nitrous Nitrogen.	Nitric Nitrogen.	Oxygen absorbed in 3 minutes at 27° C.	Oxygen absorbed in 4 hours at 27° C.	Dissolved Oxygen taken up in 48 hours at 18 C.	Dissolved Oxygen taken up in 5 days at 18° C.	Incubator Test (by smell).	Solids in Suspension.	Volatile Matter in Solids.	Solids by Centrifuge (volumes).	Rate of Filtration in gallons per cube yard.
Precipitation Liquor - -	4·94	0·51	0·02	0·08	1·72	5·44	—	—	—	5·73	3·53	60	—
Coarse Shallow Filter Effluent	0·66	0·11	0·14	3 14	0·47	1·35	0·57	1·47	12+	1·53	0·99	27	93
Do. (paper filtered)	—	—	—	—	—	1·12	—	0·48	—	—	—	—	—
Coarse Deep Filter Effluent - -	0·14	0·08	0·05	4·03	0·31	0·91	0·24	0·67	12+	1·28	0·77	26	46·5
Do. (paper filtered)	—	—	—	—	—	0·76	—	0·32	—	—	—	—	—
Fine Shallow Filter Effluent - -	0·08	0·04	0·04	4 00	0·27	0·57	0·04	0·12	12+	—	—	None.	93
Fine Deep Filter Effluent - -	0·03	0·04	Trace.	4·26	0·16	0·51	0·03	0·15	12+	—	—	Trace.	46·5

Experiment 1.

On June 17th, 1907, the four filters started working at the rate of 75 gallons per square yard for all the filters. This is equivalent to a rate of 93 gallons per cube yard for both shallow filters and 46·5 gallons for the deep filters. This rate was continued without stop until October 17th.

During the four months all the four effluents and the precipitation liquor were examined by sets of average samples drawn hourly for 8 hours, every 8 days. The figures given in Table I. are thus representative of the working of the filters under all conditions.

The filters all became mature very rapidly, so that the samples taken at the end of the experiment, in September, gave practically the same analyses as those drawn in June.

The coarse material of both deep and shallow filters was soon covered with bright green growth, as usual during the summer months. The growth was thin and had no effect on the surface æration.

The fine material was comparatively free from growth. Only a few thin rings of green slime appeared on the outer parts of the segment where the drainings from each flush of liquor chiefly fell. There was no sign of ponding on either filter. The upper layers of filtering material swarmed with small red worms.

The figures given in Table I. show very clearly the characteristics of the four effluents. Two features are at once evident—

(1) The coarse deep filter gives a much better effluent than the coarse shallow filter.

(2) The effluents from the fine deep and fine shallow filters are practically identical.

Taking the coarse filter effluents in detail, it will be noticed that the nitrification effected by the deep filter is distinctly superior to that effected by the shallow; that in the 4 hours "oxygen absorbed" test the deep has a 30% lower figure; that there is little difference in the amount of suspended matter leavng each filter. As regards the quality of this suspended matter, the aeration tests for 5 days on the original and paper-

* *See* Fifth Report of the Commission, p. 71; also Appendices III. and IV. to that Report.
† *See* Fifth Report of the Commission, Appendix I, p. 759; also Fifth Report, p. 78.

filtered samples show that the solids from the deep filter are much better oxidised than those from the shallow filter.* On this point the aeration test gives information of great value, as the "oxygen absorbed from permanganate" test is not nearly so sensitive with regard to the quality of suspended solids, especially if these come from a precipitation process. (See first section of this report, page 183). In appearance these effluents were very similar, of a brownish tinge, but quite bright, with no trace of turbidity. They had an earthy smell, often very faint.

On the other hand, if the effluents from the fine filters are compared, the deep filter has very little superiority over the shallow, the figures for both the effluents being practically the same. Neither effluent contained any appreciable suspended matter. They were sparklingly bright, with the faintest brown tinge, when looked through in depth of two feet or more. The effluent from the shallow filter was usually slightly more sparkling than that from the deep filter.

Salt Experiment No. 1.

At the conclusion of this experiment an attempt was made to find the time taken by the precipitation liquor to pass through each filter.

Fourteen lbs. of common salt were dissolved in water, and the solution poured into the tipping trough supplying each pair of filters, so as to interfere as little as possible with the natural working of the distributors. Seven lbs. of salt were thus flushed on to each filter.

Samples of the four effluents were taken, first at one minute intervals, which gradually lengthened to intervals of eight hours, over a period of 56 hours, until practically all the salt had passed through the filters. The chlorine in these samples, plotted against time of drawing, is given in diagram 2, facing page 82 of the Fifth Report of the Commission. [Cd. 4278].

Although it seems very difficult to determine the true average time taken by the liquor to pass through each filter, the following figures are of value for purposes of comparison.

—	Total quantity of salt washed out of filter in 30 hours.		Time taken for half the average quantity of salt to wash out.		Hour line upon which the centre of gravity of the curve figure falls.		Total area enclosed by the curve figure.	
	Weight in lbs.	Proportion to 7 lbs.	Hours.	Time ratio.	Hours.	Hour line ratio.	Cubic inches.	Area ratio.
Coarse shallow filter -	4·36	0·62	3·0	1·0	5·3	1·00	12·9	1·00
Coarse deep filter -	4·59	0·65	5·5	1·8	9·0	1·63	13·0	1·01
Fine shallow filter -	4·98	0·71	7·0	2.3	9·0	1·63	14·0	1·08
Fine deep filter - -	† 5·42	0.77	14·5	4·8	17·0	3·10	14·0	1·08
Average - - -	4·83	—	—	—	—	Average	13·5	—

The method of determining, by salt experiment, the time of contact during percolation, was suggested by Mr. C. C. Frye, who also calculated the figures given for the first three salt experiments. Much of the subsequent work of this report has been based on these results.

Taking the time for "half the average quantity of salt to wash out" as the best index for time of contact, the coarse deep filter gave nearly double the contact of the coarse shallow filter, and not quite so long as the fine shallow filter. The time of contact in the fine deep filter was almost exactly double that in the fine shallow.

The figures of analysis in Table I. show that the quality of the effluents was in the same order as the times of contact, the effluent from the coarse shallow filter being the least purified and that from the fine deep filter the best.

Experiment II.

On October 18th, 1907, the rate of working was increased to 150 gallons per square yard for all the filters. This is equivalent to a rate of 186 gallons per cube yard for both shallow filters and 93 gallons for the deep filters.

The filters were worked at this rate, without stop, until December 22nd, when they were rested for 7 days in cold dry weather. On December 29th they were started again at the same rate, and continued till January 28th, 1908.

The increased rate of working and the falling atmospheric temperature soon showed their effects on the nitrification, the ammonia rising and nitrate falling in all the effluents. The growths on the coarse filters began to flourish towards the end of October, and as usual slowly increased in thickness during the two following months. On the fine material growth began in November, and was sufficient to cause permanent local ponding on November 20th. This ponding was more marked on the shallow filter. On December 2nd the surface of this filter was raked over for the first time. The state of the surface of the fine filters was reflected very clearly in the analyses of their effluents. The suspended solids in the coarse shallow filter effluent increased considerably, while those in the coarse deep filter effluent remained much as before. Flushes of solid came down from the fine shallow filter, reaching as much as 3·9 parts per 100,000 in one sample, but generally there was very little over 0·8 per 100,000 in this effluent. The fine deep filter discharged hardly any solid until after the week's rest in December, when a small flush came out and quickly washed away. Generally, there was little more than a trace of solid in this effluent.

The severe frosts early in January killed off the growths on the fine filters and to a certain extent on the coarse filters also, but with the return of milder weather the surfaces were covered again in a few days. Although the filters were at times completely frozen over between the jet tracks of the sprinklers, none of the effluents deteriorated much. The coarse deep filter suffered most in this way, from its exposed position.

TABLE II.

Average Figures of Analysis for Precipitation Liquor and Effluents. Ten Analyses.

All filters working at the rate of 150 gallons per square yard.

October 22nd, 1907, to January 12th, 1908.	Ammoniacal Nitrogen.	Albuminoid Nitrogen.	Nitrous Nitrogen.	Nitric Nitrogen.	Oxygen absorbed in 3 minutes at 27° C.	Oxygen absorbed in 4 hours at 27° C.	Dissolved Oxygen taken up in 48 hours at 18° C.	Dissolved Oxygen taken up in 5 days at 18° C.	Incubator Test (by smell).	Solids in Suspension.	Volatile Matter in Solids.	Solids by Centrifuge (volumes).	Chlorine.	Rate of Filtration in gallons per cube yard per day.
Precipitation Liquor -	4·13	0·50	0·09	0·19	1·44	4·85	—	—	—	5·70	3·03	64	7·48	—
Coarse shallow filter effluent - - -	0·99	0·16	0·08	2·23	0·41	1·26	1·00	2·42	10+	2·65	1·75	53	7·05	186
Do. (paper filtered) -	—	—	—	—	—	0·87	—	0·52	—	—	—	—	—	—
Coarse deep filter effluent - -	0·55	0·10	0·07	2·69	0·27	0·94	0·51	1·40	10+	1·51	1·09	34	7·07	93
Do. (paper filtered) -	—	—	—	—	—	0·79	—	0·42	—	—	—	—	—	—
Fine shallow filter effluent - - -	0·86	0·11	0·05	2·80	0·34	0·90	0·46	1·08	10+	1·00 (approx.)	—	26	7·02	186
Fine deep filter effluent	0·35	0·06	0·03	3·25	0·24	0·60	0·21	0·42	10+	0·25 (approx.)	—	5	7·02	93

* Coarse shallow solids, *i.e.*, the mud deposited from the effluent, went putrid in 5 days at 80° F. Coarse deep solids only had a strong earthy smell after 26 days.

† 39 hours.

Table II. gives the figures of analysis for this second section of the experiment.

In comparing these results with those in Table I., allowance must be made (1) for the dilution of the sewage by the autumn rains; (2) the lower atmospheric temperature; (3) the effect of growths on the surface aeration, especially on the fine filters; (4) the solids in suspension in the fine shallow filter effluent.

The high figure, 0·86, for ammoniacal nitrogen in the fine shallow filter effluent is entirely due to surface ponding at the time three of the samples were drawn. The deep filter was also affected but not to quite the same extent, only two of the samples showing the results of the ponding.

The oxidised nitrogen shows a perfectly regular progression from coarse shallow to fine deep filter, the nitrous nitrogen falling and nitric nitrogen rising. The figure for nitric nitrogen, 2·80, in the fine shallow filter effluent would probably be nearer to that for the fine deep filter, but for the growth trouble in three samples.

Although neither is so good as in Experiment 1, the two coarse filter effluents as a whole are in the same position relatively to one another, for the deep filter is considerably better than the shallow. In suspended solids and in the figures affected by them, the shallow filter shows the effect of the increased rate of working. The aeration test is again the most sensitive.

On turning to the fine filter effluents, we find a much greater difference between the figures in Table II. and those for the corresponding effluents in Table I. than in the case of the coarse filter effluents. The ammoniacal nitrogen is ten times as high in both cases, for which the causes (2) and (3), mentioned above, are largely responsible. A comparison of the figures for the fine filter effluents in Table II. leads to the conclusion that the deep filter effluent is unquestionably the better of the two. This superiority is, however, due not so much to the direct advantage of its greater depth as to the fact that the solids had not yet worked out to the same extent as those from the shallow filter.

In appearance the coarse filter effluents showed little change after increasing the flow. They had an earthy smell, but rather stronger than before.

The fine filter effluents lost that remarkable brilliance which was so evident at the slower rate of flow. This was more marked in the shallow filter effluent, while solids in appreciable amount also appeared. The deep filter effluent never contained more than 0·3 per 100,000 of suspended matter. In the majority of samples there was only a trace of solid.

Salt Experiment 2.

Another experiment to determine the time of contact for each filter at the 150 gallon rate was made on January 23rd, 1908. The results are shown in diagram 3 facing page 86 of the Fifth Report of the Commission [Cd. 4278.]

The same amount of salt was flushed on to each filter as in Experiment 1, but as the flow of liquid had been doubled, the chlorine figures are correspondingly lower in each case.

It will be seen that the times of contact in the coarse filters were considerably more than half those found in Experiment 1, although the rate of filtration had been doubled. This is more marked in the coarse shallow filter. The fine filters, however, gave almost exactly half the time of contact given in Experiment 1.

Figures for Salt Experiment 2.

—	Total quantity of salt washed out of filter in 23 hours.		Time taken for half the average quantity of salt to wash out.		Hour line upon which the centre of gravity of the curve figure falls.		Total area enclosed by the curve figure.	
	Weight in lbs.	Proportion to 7 lbs.	Hours.	Time ratio.	Hours.	Hour line ratio.	Cubic inches.	Area ratio.
Coarse shallow filter - - -	4·20	0·60	2·27	1·00	3·8	1·00	6·38	1·00
Coarse deep filter - - -	4·87	0·69	3·00	1·32	5·6	1·48	6·53	1·02
Fine shallow filter - - -	4·17	0·60	3·70	1·63	5·8	1·53	5·63	0·88
Fine deep filter - - -	4·36	0·62	6 30	2·77	9·4	2·48	6·68	1·05
Average - -	4·40	—	—	—	—	—	6·30	—

Salt Experiment 3.

When salt experiment 2 was made, the filters were in a very different state from that which obtained in experiment 1. The development of the fungoid growth (cladothrix dichotoma) had been proceeding ever since the last experiment, so that the surfaces of the coarse filters were thickly coated. The raking of the fine material prevented this development on the other two filters.

In order to see if the difference in the ratios for time of contact was due to these growths, a third salt experiment was made immediately after experiment 2, at the original rate of 75 gallons per square yard. This experiment was carried out in exactly the same way as experiment 1.

The results are shown in Diagram 4 facing page 87 of the Fifth Report of the Commission [Cd. 4278] and in the following table of figures :—

—	Total quantity of salt washed out of filter in 46 hours.		Time taken for half the average quantity of salt to wash out.		Hour line upon which the centre of gravity of the curve figure falls.		Total area enclosed by the curve figure.	
	Weight in lbs.	Proportion to 7 lbs.	Hours.	Time ratio.	Hours.	Hour line ratio.	Cubic inches.	Area ratio.
Coarse shallow filter - - -	6·97	0·99	6·3	1·00	8·8	1·00	22·26	1·00
Coarse deep filter - - -	6·02	0·86	9·1	1·44	11·0	1·23	15·80	0·70
Fine shallow filter - - -	6·87	0·98	10·2	1·62	13·9	1·57	18·20	0·82
Fine deep filter - - -	6·29	0·90	16·9	2·68	19·6	2·16	16·28	0·73
Average - -	6·54	—	—	—	—	—	18·13	—

The times taken for half the average quantity of salt to wash out give almost the same ratios as in salt experiment 2, viz :—

Experiment 2.—1·00 : 1·32 : 1·63 : 2·77.
„ 3.—1·00 : 1·44 : 1·62 : 2·68.

The conclusion may therefore be drawn that with filters of various depths and size of material, but all in the same state, the times of contact are inversely proportional to the rates of flow.

Although the growth upset the comparison with Experiment 1., it enabled a very clear idea to be formed of the close connection between time of contact and the percentage purification effected on the liquid portion of the effluents.

With the aid of Tables I. and II. we are now in a position to see if the quality of the effluents from both coarse and fine filters of different depths depends only on the rate of working, as measured in gallons per square yard of filter area and not on the depth of the material; or, whether this rate, in conjunction with the depth of the filter, *i.e.*, the rate per *cube* yard, is the determining factor in the purification effected.

From Table 1. we see that when all the filters were working at the rate of 75 gallons per square yard, the coarse deep filter gave a considerably better effluent than the coarse shallow filter, but that with the fine material the effluents from both deep and shallow filters were practically alike. Now, as the time of contact in the fine deep filter was twice that in the fine shallow filter, it is natural to expect that the effluent from the deep should be considerably better than that from the shallow filter. Why this was not the case will perhaps be made clear from the following considerations:—

In many operations evolving the expenditure of energy, the cost of obtaining the last few units up to the maximum effect possible is very great in proportion to that needed in previous stages. For example, the coal consumption necessary to drive a ship at her maximum speed, of say 25 knots, is out of all proportion to that needed to give her a speed of 20 knots. Now, the fine shallow filter produced the very high purification of 100+19 per cent., calculated on the atmospheric oxygen taken up in the process, while the fine deep filter produced a purification of 100+20 per cent. In this case, therefore, an increase of 100 per cent. in the time of contact improved the purification by only 1 per cent. (cf. Table on p. 209.)

In Table II. there is much the same relation between the coarse deep and coarse shallow filter effluents as before, although the rate of flow had been doubled. There is less difference in the purification effected than in Experiment I., but the deep filter again gave the better effluent. It is interesting to compare this effluent, filtered at the rate of 93 gallons per *cube* yard, with the coarse shallow effluent in Table I., filtered at the same rate. Theoretically, the liquid portions of these effluents should be alike, and, allowing for difference in strength of liquor treated, this is almost exactly the case.

With the fine filters, unfortunately, it is impossible to be so sure of drawing correct conclusions from the results obtained. The aeration of both the filters was impeded by the surface growth, the shallow filter especially, probably owing to its more sheltered position. The suspended solids in the shallow filter effluent, although small in amount, are quite sufficient to account for a great part of the differences in the two analyses. Apart from suspended matter, the effluent from the fine deep filter showed about 6 per cent. better purification than that from the fine shallow filter.

The increased rate of filtration was therefore sufficient to make a distinct difference in favour of the fine deep filter.

Salt experiment 2 showed that the time of contact for the coarse deep effluent was very nearly equal to that for the fine shallow effluent. They should therefore give equal purification, although the latter was filtered at twice the rate of the former in gallons per cube yard. From the figures of analysis in Table 3, we see that this was exactly the case.

Salt experiment 1 showed that the fine shallow filter provided a rather longer time of contact than the coarse deep filter allowed. The figures in Table I. show that there was a corresponding difference in the quality of their effluents.

All the evidence therefore goes to show that, assuming sufficient aeration, it is time of contact which determines the purification that any filter can effect. This point has, in theory, already been frequently emphasized in various reports presented to the Commission by their Officers, and the experiments at Horfield, Ilford, and Accrington have borne out the contention. The various salt experiments at Dorking, however, now constitute systematic proof of its correctness. Time of contact depends upon two factors, the rate of filtration and the size and condition of the material. The depth of the filter is of importance only so far as it influences the area of filter required in each case. If local circumstances, such as the available fall, favour very shallow filters, these can quite safely be employed, provided that the area is increased to the necessary extent, and provided that the distribution of liquid on to the filter is efficient.

Experiment III.

On February 15th, 1908, the rate of working was increased from 150 to 200 gallons per square yard per day for each filter. This is equivalent to a rate of 248 gallons per cube yard for each of the two shallow filters and 124 gallons for each of the two deep filters. This rate was continued without interruption till May 23rd, when the experiment stopped.

Throughout this experiment the growth of cladothrix dichotoma was very vigorous over the surface of all the filters. It also appeared to penetrate down into the material of both coarse filters, as far as could be seen through the side walls. A certain amount of ponding occurred on both coarse filters in March and April, but it was never serious and no bad effluents resulted. This point is of interest, as in March–April, 1906, the coarse filter treating precipitation liquor was so badly choked by growth that the effluent was putrescible for a month or more, and much dead growth came away from the filter. It should be noted, however, that in 1906 (1) the filter was not fully mature, (2) the precipitant was alumino-ferric alone, instead of alumino-ferric and lime, (3) the sprinkler ran continuously, not intermittently.

The fine filters were raked over twice a week, to keep the surface open. In their case the growth did not penetrate into the filter, but if left untouched, the filters were completely flooded over in less than a week. The raking easily counteracted this, and the samples do not appear to have been much affected by deficient aeration.

The material of both the fine filters was very sodden and black looking just under the surface, with an unpleasant septic smell.

The suspended solids steadily increased in all four effluents towards the end of the experiment, especially in those from the coarse filters. The usual spring "flush out" had begun when the last two sets of samples were drawn.

This "spring flush" coincides with the seasonal decay of the fungoid growth, so that when the experiment stopped on May 23rd, the filters were almost free from this obstruction.

TABLE III.

Average Figures of Analysis for Precipitation Liquor and Effluents. Twelve Analyses.

All filters working at the rate of 200 gallons per square yard.

February 19th to May 21st, 1908.	Ammoniacal Nitrogen.	Albuminoid Nitrogen.	Nitrous Nitrogen.	Nitric Nitrogen.	Oxygen absorbed in 3 minutes at 27° C.	Oxygen absorbed in 4 hours at 27° C.	Dissolved Oxygen taken up in 48 hours at 18° C.	Dissolved Oxygen taken up in 5 days at 18° C.	Incubator Test (by smell).	Solids in Suspension.	Volatile Matter in Solids.	Solids by Centrifuge (volumes).	Chlorine.	Rate of Filtration in gallons per cube yard.
Precipitation Liquor	4·41	0·48	0·06	0·20	1·55	5·27	—	—	—	6·16	3·50	64	7.50	—
Coarse shallow filter effluent	2·09	0·29	0·05	1·44	0·68	2·20	1·66	4·39	12+	6·12	4·21	126	7·28	248
Do. (paper filtered)	—	0·12	—	—	—	1·14	—	0·77	—	—	—	—	—	—
Coarse deep filter effluent	1·06	0·16	0·04	2·64	0·52	1·34	0·72	2·06	12+	3·35	2·25	69	7·39	124
Do. (paper filtered)	—	0·09	—	—	—	0·72	—	0·48	—	—	—	—	—	—
Fine shallow filter effluent	2·13	0·21	0·05	1·76	0·55	1·70	0·82	2·94	12+	3·94	2·31	78	7·36	248
Do. (paper filtered)	—	0·12	—	—	—	1·06	—	0·63	—	—	—	—	—	—
Fine deep filter effluent	0·83	0·09	0·06	3·21	0·23	0·84	0·38	1·24	12+	1·57	0·72	20	7·37	124
Do. (paper filtered)	—	0·08	—	—	—	0·72	—	0·40	—	—	—	—	—	—

Salt Experiment 4.

After 10 sets of average samples had been drawn in Experiment III., another determination of time of contact was made, at the rate of 200 gallons per square yard. When the experiment was done on May 5th, the growth had begun to wash out from the coarse filters, especially from the shallow one.

The procedure was exactly the same as in the other salt experiments, but owing to the squally weather prevailing at the time, the distribution on the deep filters was not as regular as it should have been, the fine deep filter receiving more than its proper share of the brine, and the coarse deep filter a correspondingly smaller amount.

—	Total quantity of salt washed out of filter in 71 hours.	Proportion to 7 lbs.	Time taken for half the average quantity of salt to wash out.	
			Hours.	Time Ratio.
Coarse shallow filter - - - - -	6·96	0·99	1·5	1·00
Coarse deep filter - - - - -	4·87	0·70	4·8*	3·20
Fine shallow filter - - - - -	6·49	0·93	1·6	1·07
Fine deep filter - - - - - -	8·03	1·15	3·7*	2·47
Average - - - -	6·59	—	—	—

Although this salt experiment was not so satisfactory as the others, the times of contact are again in the same order as the quality of the effluents, as judged by the figures of analysis of samples drawn shortly before the experiment was made.

Table III. shows the figures of analysis obtained during this experiment.

The average strength of the precipitation liquor is a little higher than in Experiment II., viz., 56·4 compared with 53·7. The chief feature is the similarity of the effluents, from both pairs of filters of equal depth but of different size of material, especially as regards their liquid. In the last three sets of samples drawn in this experiment, the coarse deep filter effluent was the best of the four. This fact must be noted when the table of times of contact given above is compared with the analyses.

Generally speaking, the conclusions drawn from Experiments I. and II. are fully confirmed by Experiment III. As the rate of flow is increased, the more is the advantage of depth made evident.

In Experiment II. the coarse deep filter effected 6 per cent. higher purification than the coarse shallow, while in Experiment III. this advantage is increased to 15 per cent. The fine filters similarly show 6 per cent. and 18 per cent. superiority in the deep filter. (*Cf.* Table on p. 209.)

Experiment IV.

On May 30th, 1908, the rate of flow was raised from 200 to 250 gallons per square yard per day for all the filters. This is equivalent to 310 gallons per cube yard for the shallow and 155 gallons for the deep filters. This rate of filtration was continued for seven weeks to July 20th.

A heavy flush-out of solids occurred early in June, with the result that the suspended matter in both the coarse filter effluents and in the fine shallow filter effluent was much above the normal. The fine deep filter, however, discharged very little solid.

Throughout this experiment no trouble was caused by growths on any filter. No ponding occurred on the fine filters, and no raking was necessary.

TABLE IV.

Average Figures of Analysis for Precipitation Liquor and Effluents. Six Analyses.
All filters working at the rate of 250 gallons per square yard.

June 3rd to July 15th, 1908.	Ammoniacal Nitrogen.	Albuminoid Nitrogen.	Nitrous Nitrogen.	Nitric Nitrogen.	Oxygen absorbed in 3 minutes at 27° C.	Oxygen absorbed in 4 hours at 27° C.	Dissolved Oxygen taken up in 48 hours at 18° C.	Dissolved Oxygen taken up in 5 days at 18° C.	Incubator Test (by smell).	Solids in Suspension.	Volatile Matter in Solids.	Solids by Centrifuge (volumes).	Chlorine.	Rate of filtration in gallons per cube yard per day.
Precipitation Liquor	3·88	0·43	Trace.	0·20	1·49	4·23	—	—	—	5·51	3·71	100	8·23	—
Coarse shallow filter effluent - - -	1·78	0·33	0·11	1·58	1·02	3·12	1·33	4·83	6+	9·67	5·58	157	8·80	310
Do. (paper filtered) -	—	0·15	—	—	—	1·52	—	0·73	—	—	—	—	—	—
Coarse deep filter effluent - - -	0·48	0·21	0·10	2·73	0·77	2·25	1·27	2·54	6+	7·63	4·29	126	8·86	155
Do. (paper filtered) -	—	0·06	—	—	—	0·99	—	0·33	—	—	—	—	—	—
Fine shallow filter effluent - - -	1·33	0·25	0·08	2·48	0·77	2·37	0·67	2·25	6+	7·00	4·37	126	9·01	310
Do. (paper filtered) -	—	0·16	—	—	—	0·94	—	0·40	—	—	—	—	—	—
Fine deep filter effluent	0·47	0·12	0·09	3·16	0·55	1·43	0·48	1·35	6+	3·31	1·79	57	9·07	155
Do. (paper filtered) -	—	0·07	—	—	—	0·83	—	0·25	—	—	—	—	—	—

Table IV. gives the figures of analysis for this experiment. The precipitation liquor chanced to be rather below its average strength in the six sets of hourly samples examined, giving a calculated value of 50·1 only.

As in Experiment III., there is again a similarity in the effluents from the deep filters—of the same depth but of different-sized material. The reason for this is explained by the "time of contact" determinations.

All the effluents were bright in appearance, with an earthy smell, sometimes very faint. Every sample kept sweet on incubation, although the coarse shallow filter effluent contained 25 parts per 100,000 of suspended solids in one case.

Salt Experiment 5.

On July 14th the times of contact were determined at the 250 gallon rate of flow, with the following results:—

	Total quantity of salt washed out of filter in 31 hours.	Proportion to 7 lbs.	Time taken for half the salt to wash out.	
			Hours.	Time Ratio.
Coarse shallow filter - - - - -	6 37	0·91	0·9	1·0
Coarse deep filter - - - - -	5·84	0·83	2·5	2·8
Fine shallow filter - - - - -	6·08	0·87	2·3	2·6
Fine deep filter - - - - - -	6·07	0·87	2·6	2·9

* Half the *actual* quantity of salt washed out. In salt experiments 1, 2 and 3, the time required for half the *average* weight of salt to wash out from all four filters was taken as the time of contact. It was subsequently found that the results were more reliable if half the *actual* weight of salt washed out from each filter was taken, in place of half the average from the four, as above. If the distribution of the salt had been perfectly uniform in each experiment, the two figures would have been identical, but in practice it was impossible to secure this. In salt experiments 5 to 9, the times of contact are calculated on half the *actual* weight of salt washed out from each filter.

Here again the times of contact are in omplete agreement with the quality of the effluents, the dissolved oxygen taken up in 5 days by the paper-filtered samples being inversely proportional to the contact afforded.

It is interesting to note the effect of the flush-out of solids in the case of the shallow filters. In Experiment III. the coarse shallow filter gave 1·5 hours contact and the fine shallow filter 1·6 hours. After the discharge of solids in Experiment IV. the contact in the coarse shallow filter fell to 0·9 hour, while in the fine shallow filter it rose to 2·3 hours. This peculiar effect occurs whenever solids are discharged freely from the filters, either by natural flush-out or after the filters have been rested. The probable cause of these opposed results is discussed on page 210.

Experiment V.

On July 25th the rate of flow was further increased to 300 gallons per square yard for all the filters, *i.e.*, 372 gallons per cube yard for the shallow filters and 186 gallons for the deep filters. This rate of working was continued for ten weeks to October 7th.

The flush of solids from the filters had ceased before Experiment V. began, and all the effluents contained quite moderate amounts of suspended matter.

On August 11th both the fine filters began to pond slightly, so that raking of the surface was resumed. This ponding was not due to growths, but to clogging of the surface material by suspended matter. As the result of this, the upper layers of both fine filters had become very sodden by the time the experiment ended.

TABLE V.

Average Figures of Analysis for Precipitation Liquor and Effluents. Seven Analyses.

All filters working at the rate of 300 gallons per square yard.

July 28th to September 23rd, 1908.	Ammoniaca Nitrogen.	Albuminoid Nitrogen.	Nitrous Nitrogen.	Nitric Nitrogen.	Oxygen absorbed in 3 minutes at 27° C.	Oxygen absorbed in 4 hours at 27° C.	Dissolved Oxygen taken up in 48 hours at 18° C.	Dissolved Oxygen taken up in 5 days at 18° C.	Incubator Test (by smell).	Solids in Suspension.	Volatile Matter in Solids.	Solids by Centrifuge (Volumes).	Chlorine.	Rate of Filtration in gallons per cube yard per day.
Precipitation Liquor	4·32	0·52	Trace	0·02	1·83	5·00	—	—	—	6·09	3·91	72	9·05	—
Coarse shallow filter effluent - - -	1·53	0·22	0·17	1·79	0·72	1·92	1·02	2·79	7+	3·64	2·71	92	8·88	372
Do. (paper filtered)	—	0·11	—	—	—	1·17	—	0·64	—	—	—	—	—	—
Coarse deep filter effluent - - -	0·70	0·12	0·12	2·56	0·64	1·43	0·58	1·67	7+	2·81	1·88	69	8·92	186
Do. (paper filtered)	—	0·07	—	—	—	0·94	—	0·34	—	—	—	—	—	—
Fine shallow filter effluent - - -	1·47	0·19	0·11	2·13	0·67	1·75	0·73	2·41	7+	3·44	2·18	68	8·81	372
Do. (paper (filtered)	—	0 11	—	—	—	1·05	—	0·48	—	—	—	—	—	—
Fine deep filter effluent	0·80	0·12	0·17	2·39	0·51	1·46	0·37	1·38	7+	2·53	1·64	49	8·86	186
Do. (paper filtered)	—	0·07	—	—	—	1·03	—	0·43	—	—	—	—	—	—

The figures of analysis are given in Table V. It will be noticed that the effluent from the coarse deep filter is now for the first time the best of the four. The coarse shallow filter effluent is still the worst, but it is actually better, as regards its liquid portion, than it was at the 250 gallon rate in Experiment IV. The time of contact determinations will explain this apparently contradictory result.

All the four effluents of Experiment V. were good, and caused no objectionable growths when run along 50 yards of channel.

Salt Experiment 6.

On October 6th the times of contact were determined at 300 gallons per square yard, with the following results :—

	Total quantity of salt washed out of filter in 27 hours.	Proportion to 7 lbs.	Time taken for half the salt to wash out.	
			Hours.	Ratio.
Coarse shallow filter - - - -	6·30	0·90	1·5	1·0
Coarse deep filter - - - - -	6·71	0·96	2·8	1·9
Fine shallow filter - - - - -	6·53	0·93	1·7	1·1
Fine deep fiiter - - - - - -	6·01	0·86	3·6	2·4

On comparing these figures for time of contact with those for Salt Experiment No. 5, it will be seen that the coarse shallow filter shows a marked increase, indicating the retention of suspended solids in the filter. From the tables of analysis, the solids in this effluent have fallen from 9·7 to 3·6, while the improvement in the purification of the liquid portion of the effluent is correspondingly higher. Both the deep filters show a smaller increase in their times of contact, but in their case the effluents do not show a similar variation as regards purification. It is probable that the change from 250 to 300 gallons is too small to permit a fair comparison between the average figures of analysis for ten weeks and the times of contact determined on one day only at the end of that period.

Experiment VI.

As the information to be gained by further small increases of flow was not likely to be of much value, it was decided to raise the rate of filtration from 300 to 450 gallons per square yard for all the filters, and this was accordingly done on October 7th. It was intended that this rate, which is equivalent to 558 gallons per cube yard on the shallow filters, should test these to the point of breakdown. The experiment lasted for seven weeks, to November 28th.

Throughout this experiment the fine filters were raked daily, but this did not prevent them becoming ponded on the surface. At the end of the experiment the fine shallow filter was so water-logged that the tank liquor ran over the edge in two or three places. The coarse material was not at all ponded, although it became covered with the fungoid growth usual at this season.

TABLE VI.

Average Figures of Analysis for Precipitation Liquor and Effluents. Six Analyses.
All filters working at the rate of 450 gallons per square yard.

October 14th to November 24th, 1908.	Ammoniacal Nitrogen.	Albuminoid Nitrogen.	Nitrous Nitrogen.	Nitric Nitrogen.	Oxygen absorbed in 3 minutes at 27° C.	Oxygen dissolved in 4 hours at 27° C.	Dissolved Oxygen taken up in 48 hours at 18° C.	Dissolved Oxygen taken up in 5 days at 18° C.	Incubator Test (by smell).	Solids in Suspension.	Volatile Matter in Solids.	Solids by Centrifuge (volumes).	Chlorine.	Rate of Filtration in gallons per cube yard per day.
Precipitation Liquor	4·67	0·54	0·00	0·02	2·01	5·86	—	—	—	9·34	5·95	108	9·45	—
Coarse shallow filter effluent - - -	3·49	0·37	0·07	0·56	0·89	2·87	2·63	6·19	2 + 4 −	6·90	4·18	122	9·27	558
Do. (paper filtered) -	—	0·20	—	—	—	1·46	—	1·35	5 + 1 ?					
Coarse deep filter effluent - - -	1·98	0·28	0·15	1·63	0·63	2·10	1·25	5·06	6 +	5·79	3·94	133	9·07	279
Do. (paper filtered) -	—	0·15	—	—	—	1·01	—	0·76						
Fine shallow filter effluent - - -	3·44	0·38	0·05	0·53	0·94	3·21	2·21	5·62	1 + 4 − 1?	7·48	5·15	112	9·18	558
Do. (paper filtered) -	—	0·24	—	—	—	1·72	—	2·15	1 + 2 − 3?					
Fine deep filter effluent - - -	2·25	0·24	0·11	1·94	0·43	1·87	0·94	5·00	6 +	4·30	2·90	76	9·04	279
Do. (paper filtered) -	—	0·14	—	—	—	1·11	—	0·92						

The figures of analysis for this experiment are given in Table VI. They show that the shallow filters were now past their limit for the production of a non-putrescible effluent, since only two samples out of six in each case withstood incubation. These were both from the weakest night sewage. The paper-filtered samples of effluent only gave two samples which failed to withstand incubation, both being from the fine shallow filter. It is interesting to note that this effluent is the only one which is below the provisional standard of 1·5 parts per 100,000 of dissolved oxygen taken up in 5 days. The deep filter effluents were always non putrescible. The liquid portions of both shallow filter effluents show 74 per cent purification, as calculated on the atmospheric oxygen used up, while the liquid portions of the deep filter effluents also show identical purification, viz., 91 per cent. With the filters in the state they were in at this time, the size of the material made no difference in the purification effected on the liquid.

In appearance the shallow filter effluents were both very turbid and smelt slightly of sewage. The deep filter effluents were either bright looking or slightly turbid, with a clean earthy smell.

Salt Experiment 7.

The times of contact for the four filters at 450 gallons per square yard were determined on October 8th, as follows :—

	Total quantity of salt washed out of filter in 27 hours.	Proportion to 7 lbs.	Time taken for half the salt to wash out.	
			Hours.	Time Ratio.
Coarse shallow filter - -	7·32	1·05	1·1	1·0
Coarse deep filter - - -	5·22	0·75	1·6	1·4
Fine shallow filter - -	6·23	0·89	1·3	1·2
Fine deep filter - - -	6·89	0·98	2·4	2·2

These results are especially interesting, because they show that a contact of one hour is insufficient to produce an uniformly non-putrescible effluent from a liquor of strength 57 ; while 1·5 hours contact will yield an effluent of fair quality. It is true that in Experiment IV. a contact of 0·9 hour on the coarse shallow filter gave a non-putrescible effluent, but this was in July, under the climatic conditions most favourable for nitrification. It is certain that in the winter this would be quite insufficient.

Experiment VII.

Up to now the deep and shallow filters had all treated precipitation liquor at the same rate of flow per *square* yard, so that the rate per cube yard was in each case twice as high for the shallow as for the deep filters. In the following experiment the shallow filters were worked at the rate of 350 gallons per square yard and the deep filters at 700 gallons. For the reasons which will be detailed in Part IV., these rates, which are equivalent to one of 434 gallons per cube yard for each of the four filters, were indicated as the highest at which the filters could treat the precipitation liquor, so as to yield an effluent, uniformly non-putrescible, and which would not take up more than 1·5 parts per 100,000 of dissolved oxygen in 5 days. The efficiency of a cube yard of the different filters could thus be directly compared.

In order to allow the shallow filters to recover from the effects of the last experiment, the tank liquor was shut off from all four, while the fine material was dug over several times. On first digging into the fine clinker, it was found that in both deep and shallow filters there was a layer about 1 foot deep which was black and slimy, contained no worms, and had a strong "septic" smell. The shallow filter was rather more sodden than the deep, and the black layer had a stronger smell. Below this the material was brownish and fairly clean, with an earthy smell ; many worms were to be seen in this portion.

On January 4th, 1909, the tank liquor was turned on to the filters, which continued to work till April 1st. In order that the interval between the flushes of tank liquor might be the same on both deep and shallow filters, a new tipping trough, holding 10 gallons, was fitted to the deep filters in place of the 5 gallon trough used up to now.

On January 7th the times of contact were determinated by salt experiment 8, with the result shown in the table below. Throughout this experiment the weather was unusually cold, hence the efficiency of all the filters was below the normal. The fine filters had to be raked frequently ; the coarse material was forked over early in February, as the growth was then becoming obstructive, but was not touched again. On March 30th, the times of contact were tested by salt experiment 9. The results are tabulated with those obtained at the beginning of the experiment on January 7th.

———	Salt experiment 8. Jan. 7th, 1909. Time of contact in hours.	Salt experiment 9. March 30th, 1909. Time of contact in hours.
Coarse shallow filter -	1·11	1·42
Coarse deep filter -	1·25	1·43
Fine shallow filter -	1·95	1·81
Fine deep filter -	2·14	2·13

The coarse filters had thus increased their time of contact slightly, while the fine filters were practically the same as at the beginning of the experiment. Arguing from previous experience, this result should indicate (1) that the coarse filters had either retained considerable quantities of suspended solids, or that growth was flourishing in them ; the latter was the actual cause of the increased contact—an effect similar to that observed in these filters in Experiment II., (2) that the fine filters had discharged sufficient solids to keep the amount held up in the material fairly constant, and that they were not affected by growths.

TABLE VII.

Average Figures for Precipitation Liquor and Effluents. Nine Analyses.
All filters working at the rate of 434 gallons per cube yard.

January 12th to March 20th, 1909.	Ammoniacal Nitrogen.	Albuminoid Nitrogen.	Nitrous Nitrogen.	Nitric Nitrogen.	Oxygen absorbed in four hours at 27° C.	Dissolved oxygen taken up in five days at 18° C.	Incubator Test (by smell).	Solids in Suspension.	Volatile matter in Solids.	Solids by Centrifuge. (Volumes).
Precipitation Liquor	4·55	0·50	0·06	0·33	6·16	—	—	5·70	3·05	74
Coarse shallow filter effluent	3·70	0·32	0·12	0·62	2·94	4·98	5 + 3 — 1 ?	6·07	4·23	105
Coarse shallow (paper filtered)	—	0·19	—	—	1·56	1·65	8 + 1 —	—	—	—
Coarse deep filter effluent	3·65	0·28	0·07	0·72	2·33	3·73	7 + 2 —	4·06	2·92	77
Coarse deep (paper filtered)	—	0·16	—	—	1·33	1·45	8 + 1 —	—	—	—
Fine shallow filter effluent	3·10	0·23	0·07	1·14	2·41	3·01	9 +	5·29	3·78	103
Fine shallow (paper filtered)	—	0·17	—	—	1·14	1·15	9 +	—	—	—
Fine deep filter effluent	3·53	0·25	0·03	0·91	2·27	3·19	9 +	4·32	3·01	80
Fine deep (paper filtered)	—	0·16	—	—	1·36	1·50	9 +	—	—	—

The figures of analysis for this experiment are given in Table VII. They show that the rate of 434 gallons per cube yard was too high to enable the coarse filters to produce the purification desired, as three out of nine samples of shallow filter effluent and two out of nine of deep filter effluent went putrid on incubation, while the dissolved oxygen taken up in five days by the paper-filtered samples was unsatisfactory in three of the effluents. The fine shallow filter effluent was in most respects the best effluent of the four. This result lends support to the claim that fine material is most efficient when arranged in the form of a shallow rather than a deep filter. In this experiment the filters were working right up to their limit, but in the next and final experiment it will be seen that this was also true when they were working at the practical rate of 150 gallons per cube yard per day.

Experiment VIII.

In Experiment VII. the filters were all somewhat overloaded and the effluents were consequently of poor quality. Under these conditions the fine shallow filter was slightly more efficient than the other three. In order to see if the filters would show the same relative efficiency when producing a good effluent, the rate of flow was reduced to 150 gallons per *cube* yard per day for all the filters. This rate is that recommended by the Commission in their Fifth Report for the filtration of precipitation liquor of average strength (50 to 60) on coarse percolating filters. The contacts given at a rate of 150 gallons per cube yard should be 2·2 hours for coarse material and 4·4 hours for fine material, producing a purification on the liquid portion of the effluents of 100 and 100 + 13 per cent. respectively.†

The experiment lasted for six weeks, from April 13th to May 25th, during which time 4 sets of average samples were examined. The samples were drawn hourly for 24 hours in each case, instead of for 8 hours as in all the preceding experiments on the deep and shallow filters, so as to secure a representative analysis in less time. Each analysis was therefore equivalent to three on the old system (apart from the question of time covered by the experiments).

The seasonal decay of growth and the spring flush-out again coincided during this experiment, so that the solids were high in all the effluents. The fine filters required a little raking at first, but after three weeks needed no further attention ; the coarse filters were not touched.

TABLE VIII.

Average Figures for Precipitation Liquor and Effluents. Three Analyses.
All filters working at the rate of 150 gallons per cube yard.

April 16th to May 5th, 1909.	Ammoniacal Nitrogen.	Albuminoid Nitrogen.	Nitrous Nitrogen.	Nitric Nitrogen.	Oxygen absorbed in four hours at 27° C.	Dissolved oxygen taken up in five days at 18° C.*	Incubator Test (by smell).	Solids in Suspension.	Volatile matter in Solids.	Solids by Centrifuge (Volumes).
Precipitation Liquor	4·11	0·66	0·00	0·17	5·11	—	—	7·26	4·58	78
Coarse shallow filter effluent	1·71	0·61	0·13	2·04	3·77	5·97	3 +	12·3	8·0	259
Coarse shallow (paper filtered)	—	0·17	—	—	1·13	0·62	—	—	—	—
Coarse deep filter effluent	1·56	0·50	0·11	2·14	4·32	6·63	3 +	15·4	9·3	328
Coarse deep (paper filtered)	—	0·12	—	—	1·08	0·46	—	—	—	—
Fine shallow filter effluent	0·53	0·20	0·07	3·61	1·86	2·04	3 +	5·1	2·9	104
Fine shallow (paper filtered)	—	0·09	—	—	0·73	0·46	—	—	—	—
Fine deep filter effluent	0·78	0·19	0·07	3·27	1·78	2·06	3 +	5·4	3·0	113
Fine deep (paper filtered)	—	0·09	—	—	0·72	0·41	—	—	—	—

* The third set of 24 hours' samples, drawn May 5th and 6th, gave figures for dissolved oxygen taken up in 5 days by the paper-filtered samples of effluent which were in each case extraordinarily high, while all the other figures of analysis were in agreement with the first two sets. These figures were: Coarse shallow, 2·23; Coarse deep, 2·6 + x; Fine shallow, 1·16; Fine deep, 1·20. As no explanation of this discrepancy could be found, a fourth set of samples was drawn on May 21st and 22nd, and these gave normal figures in each case. In the above table the high figures are omitted, as their inclusion would have given misleading averages.

The figures of analysis given in Table VIII. show that the fine shallow filter was again the most efficient of the four. Owing to the flush-out of dead growth and other suspended matter, the figures for 'oxygen absorbed' and other tests affected by solids are very high in the effluent from both the coarse filters. Nitrification was, however now so active that no samples became putrid on incubation. The appearance of the effluents was satisfactory, and they all had a clean earthy smell.

† Comparing the liquid portion of the effluent with the whole precipitation liquor (liquid and solid together).

	Experiment VII. Precipitation Liquor (strength 62) filtered at 434 gallons per cube yard on all four filters.						Experiment VIII. Precipitation Liquor (strength 55) filtered at 150 gallons per cube yard on all four filters.					
	Whole Effluent, including Suspended Solids.			Effluent without Suspended Solids.			Whole Effluent, including Suspended Solids.			Effluent, without Suspended Solids.		
	Strength or Oxidisability of Effluent.	Units of Purification effected by 1 cube yard of filter.	Percentage Purification.	Strength or Oxidisability of Effluent.	Units of Purification effected by 1 cube yard of filter.	Percentage Purification.	Strength or Oxidisability of Effluent.	Units of Purification effected by 1 cube yard of filter.	Percentage Purification.	Strength or Oxidisability of Effluent.	Units of Purification effected by 1 cube yard of filter.	Percentage Purification.
Coarse shallow filter.	26·1	15,540	58	16·5	19,720	74	23·1	4,792	58	3·1	7,786	94
Coarse deep filter.	22·6	17,060	63	15·7	20,060	75	23·7	4,697	57	1·7	7,993	97
Fine shallow filter.	20·6	17,940	67	12·1	21,640	81	−0·9	8,379	102	−7·6	9,394	114
Fine deep filter.	21·4	17,580	65	14·6	20,550	76	−1·4	8,048	98	−5·5	9,075	110

The above table is a summary of the work done by the filters* in Experiments VII. and VIII., in which the chief points of interest are :—

(1) A cube yard of coarse material effects practically the same amount of purification whether it forms part of a deep or a shallow filter, when both the liquid and suspended solids of the effluent are considered; the same thing is true when the liquid portions of the effluents, without suspended solids, are compared. Further, this statement applies both to filters worked at their greatest or rather beyond their greatest capacity, as in Experiment VII., as well as to filters working well within their limits, as in Experiment VIII. The small difference in efficiency is usually in favour of the deep filter. These Dorking experiments, in which the distribution was much more uniform, are thus in agreement with the earlier experiments at Horfield and Ilford.

(2) A cube yard of fine material will effect a little more purification when arranged in the form of a *shallow* rather than of a deep filter. This holds both for maximum and moderate rates of flow, but the advantage of the shallow filter is only about 5 per cent. at most. Still, it is certain that with sewage liquors containing more suspended matter than the liquor used in these experiments, this difference would be accentuated in favour of the shallow filter.

(3) For the reasons explained in Part IV. of this report, it was expected that in Experiment VIII. the coarse material would effect a purification of 100 per cent., calculated on the effluent without suspended solids. The purifications actually effected by the deep and shallow filters were 97 and 94 per cent. respectively. The flush out of growth and other retained suspended matter having lowered the times of contact, the purifications are consequently rather below the normal. In the case of the fine material the agreement is good; 100 + 13 per cent. was expected and 100 + 10 and 100 + 14 per cent. purification were actually effected.

Summary of Conclusions.

The chief conclusions to be drawn from these experiments are as follows :—

(1) Given adequate aeration, the purification effected by a percolating filter upon any sewage liquor is mainly determined by the average time during which the liquor is in contact with the material. For a liquor of one particular strength at a constant temperature, the purification is a function of the time of contact.

(2) It follows from the above that, with a given volume of sewage liquor passing through a filter, the deeper the filter the better will be the quality of the resulting effluent, because the average time of contact increases with the depth of the filter. This holds good for both coarse and fine material, provided that the preliminary tank treatment is suitable and that the filter shows no clogging of the surface. It must be noted that if a filter is worked at a low rate of flow, so as to give a high degree of purification, a large increase in the time of contact can only produce a very small improvement in the effluent. On the other hand, at high rates of flow the benefit of depth is most evident.

(3) A cube yard of coarse material, 1 to 4 inch, will effect practically the same amount of purification on a given volume of sewage liquor, whether it is arranged in the form of a deep or of a shallow filter. The deep form is to be preferred, because any errors of distribution are neutralised more completely and the contact is consequently longer.

A cube yard of fine material, $\frac{1}{8}$ to $\frac{1}{2}$ inch, will effect a little more purification when arranged as a shallow rather than as a deep filter. In this case the advantage is not due to longer contact, for, as with coarse material, the time of percolation is greater in the deep filter. The explanation is probably to be found in the more effective aeration of the fine material in a shallow form, while a deep filter cannot utilise its longer contact to such advantage.

(4) The average time of contact afforded by a clean filter depends on three factors : (*a*) the size of the material, (*b*) the nature of its surface, and (*c*) the rate of filtration.

The time of contact given by any filter at a constant rate of flow will vary considerably with changes in the amount of suspended matter held up by the material. The effect of this is to increase the time of contact in filters of coarse material and so to improve the effluent, always provided that the amount of solid so held up is not sufficient to choke any portion completely. This latter stage was not reached in the Dorking experiments. With fine material the time of contact is reduced at a much earlier stage than with coarse material, for at the end of Experiment III. the time of contact for the fine deep filter was less than that given by the coarse deep filter at the same rate of flow. In Experiments IV., V., and VI. the size of the material had very little effect on the purification.

PART IV.—THE DESIGN OF PERCOLATING FILTERS.

Percolating filters have usually been designed more in accord with general experience and individual preference than on any fixed principle. So many cubic yards of filtering material have been provided, and it has sometimes been left to the manager responsible for the working of the installation to discover, by the method of trial and error, at what rate of flow the sewage liquor can be treated so as to yield a satisfactory effluent. Such methods may lead in many cases either to an insufficiency of filtering material, making the production of a uniformly good effluent impossible, or to an unnecessary outlay upon the plant. Examples of both these defects could be pointed out. It is hoped that what follows will show, at any rate in some measure, how such errors of design may be avoided in the future.

The deep and shallow filter experiments described in Part III. of this report, have shown that the average time taken by the sewage liquor to pass through a

* *Cf.* Memorandum on the estimation of the work done by sewage filters . . ., by Dr. McGowan and Mr. Frye; this Appendix p. 10.

percolating filter is the essential factor which determines the purification effected. In the course of these experiments a large number of estimations of "times of contact" have been made by the method described on page 201.

A system of general application to the design of percolating filter installations, such as will enable the designer to produce, within fairly close limits, the purifying effect required, can now be based upon the following data :—

Strength of sewage and oxidisability of effluents;

Time of contact in percolating filters.

The strength of the sewage liquor to be treated on the filters is expressed in terms of the weight of oxygen necessary to completely oxidise 100,000 parts of the liquor. This can be determined by direct experiment upon a series of representative samples, either by the now well-known dilution method of aeration, worked out by Dr. Adeney, of fermenting a portion with excess of aerated tap water, or by his more rapid method of shaking the sample with excess of air. Both these methods however take a considerable time to carry out, and in practice the method of calculating the oxidisability of the liquor from its figures of analysis would usually—if not always—suffice. This must be regarded as a rapid method of arriving at a result only to be obtained directly by a somewhat tedious process.

The strength of the sewage liquors referred to in the following pages are all calculated by applying the formulæ given in Dr. McGowan's memorandum on the strength of sewage* to the average figures of analysis. Although this method of calculation gives necessarily only an approximation to the true value, the results of its application are such as to show that it is sufficiently accurate for practical purposes.

In what follows, the purification effected by the filters is expressed by the difference between the oxidisability of the effluent *without its suspended solids* and the strength of the sewage liquor. Thus, if a tank liquor of strength 100, *i.e.*, one which requires, theoretically, 100 parts by weight of oxygen for the complete oxidation of the ammonia and organic matter contained in 100,000 parts of it, is said to have undergone "80 per cent. purification," it means that 80 parts of atmospheric oxygen have been taken up and that the effluent is still capable of taking up 20 parts more. The oxidisability of the effluent, without its suspended solids, is calculated from the formula :—

$$(\text{Ammoniacal} + \text{Organic Nitrogen}) \times 4{\cdot}5 - \text{Nitric N.} \times 3.$$

The reasons for adopting this formula, as one for practical application, are set out in the memorandum by Dr. McGowan and Mr. Frye, on "Work done by Filters."† In that paper, also, on p. 49, the true theoretical formula is indicated.

The figure given by the above formula will have a *negative* value if the effluent is well purified, and therefore relatively rich in nitrate. In such cases the figure denoting the percentage purification will be greater than 100, the excess being a measure of the oxygen held in reserve as nitrate. "Percentage purification," used in this connection, has thus a meaning other than that usually understood by this term.

Only the liquid portion of the effluent is considered here, and not the whole effluent containing suspended solids, because the latter vary so greatly both in amount and in power of absorbing oxygen, even from one filter at a constant rate of flow, that it is not possible to make satisfactory comparisons, or to predict their effects with any certainty. By taking the solids by themselves, it is possible to give an approximate estimate of their average amount in the effluent, and also some idea of their oxidisability. This point will be referred to again.

Relation of Time of Contact to Purification.

The table given below shows the relation between the average time of contact and the percentage purification effected by the filters in the various experiments. The purifications are calculated from the average figures of analysis given in the preceding section of this report, and are derived from 265 8-hours average samples, or 2,120 separate samples of tank liquor and effluents. Each figure represents the average value of the work done by the filters during periods of 7 to 14 weeks.

1. No. of Experiment.	2. Filter.	3. Rate of flow in gallons per cube yard.	4. Percentage Purification.	5. Time of contact in hours.	6. Strength of liquor.	Remarks.
1	Fine deep	46·5	120	14·5	61	
1	Fine shallow	93	119	7·0	61	
1	Coarse deep	46·5	118	5·5	61	
2	Fine deep	93	115	6·3	54	
4	Fine deep	155	113	2·6	50	
4	Coarse deep	155	111	2·5	50	
2	Fine shallow	186	109	3·7	54	
3	Fine deep	124	109	3·7	56	
1	Coarse shallow	93	109	3·0	61	
2	Coarse deep	93	109	3·0	54	
5	Coarse deep	186	107	2·8	56	
5	Fine deep	186	105	3·6	56	
3	Coarse deep	124	104	4·8 (?)	56	
2	Coarse shallow	186	103	2·3	54	
4	Fine shallow	310	100	2·3	50	
5	Fine shallow	372	98	1·7	56	
5	Coarse shallow	372	95	1·5	56	
6	Fine deep	279	91	2·4	62	Much ponded.
3	Fine shallow	248	91	1·6	56	
6	Coarse deep	279	91	1·6	62	
4	Coarse shallow	310	91	0·9	50	
3	Coarse shallow	248	89	1·5	56	
6	Fine shallow	558	74	1·3	62	Much ponded.
6	Coarse shallow	558	74	1·1	62	

On the other hand, it has to be borne in mind that the times of contact represent the state of the filters on *one* day in each experiment, usually at the end of the period. This probably accounts for some of the discrepancies in the table, for one of the striking facts brought out by the salt experiments is the gradually changing conditions of percolating filters as regards time of contact.

The time of contact determination should properly have been made in the middle of each section of the experiment, or better, two determinations should have been done, one at the beginning and one at the end, the mean being taken as the correct value. This latter method would also have given much valuable information on the influence of retained suspended matter on the time of contact, a point on which we have at present only general qualitative observations. The average strength of the precipitation liquor used in the experiments varied from 50 to 62, this variation of course influencing the percentage purification figures.

The figures given in columns 4 and 5 above are plotted in Diagram I. When allowance is made for changes of season, and for the difficulty of controlling such outdoor operations with any delicacy, the results

* This Appendix, p. 1.

† This Appendix, p. 10 *et seq.*

are as regular as could reasonably be expected. This curve only applies directly to a sewage liquor of strength 57, but since the times of contact necessary to effect equal purification are approximately proportional to the strengths of the liquors,* the times of contact for any other strength can be easily calculated.

The limits of purification for this curve are 70 and 100 + 20 per cent. For a domestic or mainly domestic sewage of average strength these extremes are equivalent, respectively, to an effluent just putrescible on incubation for 5 days and to one of very great purity, in which practically the whole of the nitrogen is present as nitrate, and which takes up no dissolved oxygen when incubated for 5 days at 18° C.

From the curve in Diagram I it is possible to find the time of contact necessary to produce any required purification on the sewage liquor to be treated by the filters. But this is of little value unless it is known how the proper contact may be given.

Now, time of contact in percolating filters depends on several factors, of which the most important are the rate at which the liquor is passed through the filters and the size and nature of the material. The state of the material as regards fungoid growth and, especially, the amount of solid matter held up in the filter have also an important influence on the time of contact.

The method of distribution is also of importance, especially in shallow filters of coarse material, but in what follows the liquor is assumed to be evenly distributed over the surface of the filter, so that every square yard receives an equal amount.

In the Dorking experiments only two sizes of one kind of material have been used, viz., 1 to 4 inch and ⅛ to 1 inch hard gas clinker. These sizes, however, approximate to those in use in a large number of existing installations of percolating filters, and, as will be seen subsequently, these filters give results in close agreement with the theory advanced here.

Relation of Rate of Flow to Time of Contact.

The values given in columns 3 and 4 of the table on page 209 are plotted in Diagram 2, giving curves for each of the two grades of clinker. These curves represent a purely physical relation, viz., the average time taken by a particle of water to pass through the different filters at various rates of flow. They are thus quite independent of the strength of the liquor.

The figures show that the depth of the filters has practically no influence on time of contact when they are worked at equal rates of flow per *cube* yard. The following pairs of observations illustrate this :—

Filter.	Rate of filtration in gallons per cube yard.	Time of contact in hours.
Coarse shallow -	93	3·0
Coarse deep -	93	3·0
Fine shallow -	93	7·0
Fine deep -	93	6·3
Coarse shallow -	183	2·3
Coarse deep -	186	2·8
Fine shallow -	186	3·7
Fine deep -	186	3·6

In all the above pairs of observations, the time of contact for the deep filters was determined at a later date than that for the shallow filters. As the state of the material may have changed in the intervals, these results are not strictly comparable. It is, however, probable that if two filters of similar material in the same state, one deep and the other shallow, were tested simultaneously at equal rates of flow per cube yard, the deep filter would show a slightly longer time of contact than the shallow, because any errors in distribution have less effect on the former.†

A salt experiment was made on January 7th, 1909, with all four filters working at the same rate of 434 gallons per cube yard. They had rested for five weeks, and the material of the fine filters had been dug over several times.

The times of contact found in this case were :—

Filter.	Time of contact in hours.
Coarse shallow - - - - - -	1·11
Coarse deep - - - - - - -	1·25
Fine shallow - - - - - - -	1·95
Fine deep - - - - - - -	2·14

These results are in agreement with the view expressed above. The four filters had all received the same amount of sewage since they were re-constructed 18 months before.

The amount of suspended matter held up by the material has a marked influence on the time of contact, especially with fine grades of ½ inch and under. With coarse material the effect of this retained solid is to increase the time of contact, from that given by new material, up to a certain point, determined by the season and the rate of flow, at which a balance seems to be reached, the solids passing out as rapidly as they enter the filter.

With fine material, on the other hand, the time of contact is *reduced* by the retention of suspended matter, as will be clearly seen on referring to the curves in Diagram 2. Here the dotted line shows the results obtained from the ⅛ to ½ in. clinker, when this had been at work long enough for the interstitial spaces to become more or less choked. Under such conditions the liquor is forced to travel at unequal rates through the medium, as certain parts become waterlogged.

It will be seen that the time of contact is gradually reduced, so that at a rate of 550 gallons per cube yard it is no longer than that afforded by the coarse material at the same rate of flow.

This effect is of some importance, for it means that under certain conditions the working of mature filters is independent of the size of material of which they are constructed. There was no breaking down of the fine material, which was all prepared by hand from the hardest clinker and is still in perfect condition.

In order to compare the results obtained at various places where fine material is in practical use, with the Dorking results, the curve for this grade has been assumed to run parallel to that for coarse material, but no estimations of time of contact have been made on clean or almost clean material at rates above 200 gallons per cube yard.

The experiment referred to above, at 434 gallons per cube yard for all four filters, illustrates the effect of rest very strikingly. After the fine filters had been idle for five weeks and had been dug over several times, the time of contact increased again to nearly double its former value, *i.e.*, it was 2·0 hours instead of the theoretical time of 2·5 hours for clean material. On the other hand, the time of contact for the coarse filters, which were not dug over, agreed very closely with the curve previously drawn, which shows 1·2 hours as the theoretical time.

Having disposed of the necessary preliminary details, the main question may now be stated as follows :

Given a sewage liquor of any kind that does not contain large quantities of trade waste, which is to be converted into an effluent of a certain purity, by treatment on percolating filters of any type and grade of material, at what rate in gallons per cube yard per day must the liquor be passed through the filter?

(1) The strength of the liquor to be treated must first be calculated from several thoroughly representative analyses, using the following formula :—

$$(\text{Am. N.} + \text{Org. N.}) \times 4{\cdot}5 + \left\{ \begin{matrix} \text{Oxygen absorbed} \\ \text{in 4 hours.} \end{matrix} \right\} \times \begin{matrix} 6{\cdot}5‡ \\ 6{\cdot}0§ \end{matrix}$$

The analysis from which the calculation is made should be the average of several 24 hours samples, and if the extreme dry weather figures are available, they will be of value.

(2) The quality of the effluent it is desired to produce has then to be decided. This is expressed by the "percentage purification" to be effected on the liquid portion of the effluent, allowing credit for the oxygen contained as nitrate.

For the reasons already given, the suspended matter in the effluent is not considered in this calculation, but it may be taken as broadly true that the amount of solid in the sewage liquor will determine the amount in the effluent and that in this respect the method of filtration is of small importance, at least in all cases where the filters run continuously and no periodic washing of the material has to be carried out.

Effluents may be divided here into three classes :—

I. Effluents showing over 100 + 10 per cent. purification. Such effluents have practically all their nitrogen oxidised to nitrate, and retain 90 per cent. of their dissolved oxygen after 5 days incubation at 18° C.

II. Effluents showing from 90 to 100 + 10 per cent. purification. Effluents of this kind are what are ordinarily classed as "very fair to very good." The ratio of oxidised to unoxidised nitrogen varies from 1 : 1 to 3 : 1, and the dissolved oxygen taken up in 5 days from 1·0 to 0·5 part per 100,000. No effluents of this class gave rise to objectionable growth in the Dorking channel experiments.

* Cf. Memorandum on "Estimation of the Work done by Sewage Filters * * * "; this Appendix.
† See Ilford Experiments (*loc. cit.*) ‡ 6·5 for sewages and septic tank liquors. § 6·0 for precipitation liquors.

DIAGRAM Nº 1.

SHOWING RELATION OF TIME OF CONTACT TO PERCENTAGE PURIFICATION

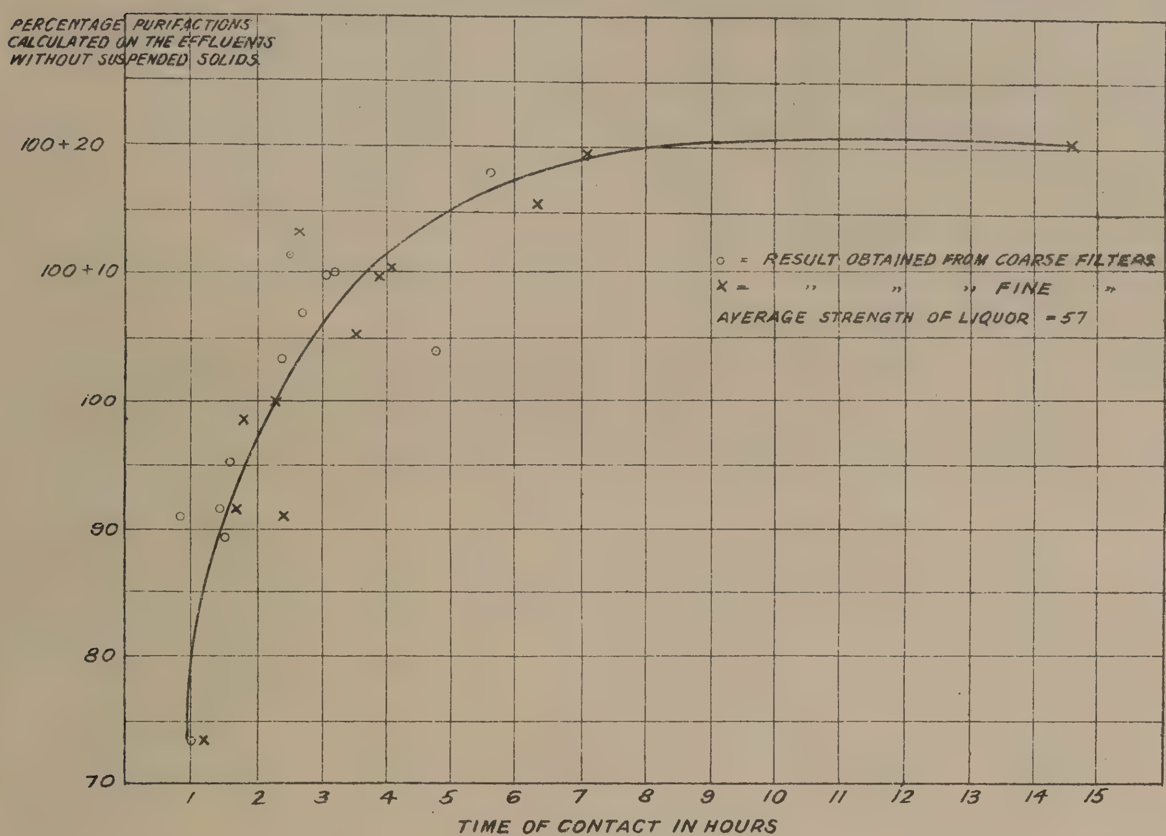
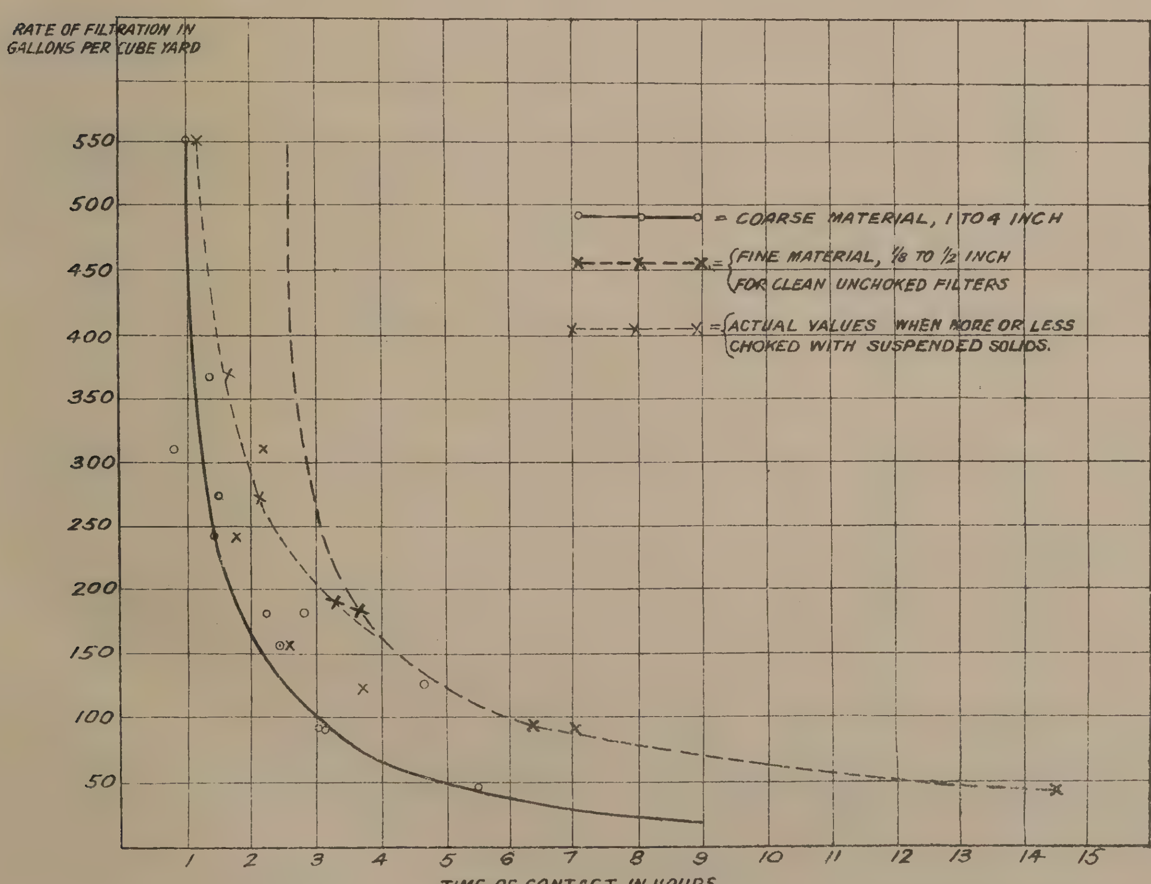


DIAGRAM Nº 2.

SHOWING RELATION OF TIME OF CONTACT TO RATE OF FILTRATION.



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III. Effluents showing from 70 to 90 per cent. purification. These are usually termed "poor to fair"; while generally non-putrescible in five days, they are imperfectly purified, and would not be suitable for discharge into streams where a high class effluent was necessary. Effluents of this class encouraged grey fungus during the winter months in the channels along which they flowed at Dorking.

(3) Having fixed the class of effluent required, the time of contact necessary to effect this purification on a liquor of strength 57 can be read off from the curve in Diagram 1. By simple proportion the time of contact for the liquor to be treated can then be found.

(4) It only remains to find the proper rate of filtration in gallons per cube yard per day, from curves similar to those in Diagram 2, which relate to 1 to 4 inch and $\frac{1}{8}$ to $\frac{1}{4}$ inch clinker.

Two examples, taken from the records of the working of the percolating filters at different places, will make the method clear.

Example 1.

A septic tank liquor is to be treated on percolating filters of coarse clinker. The effluent is to show 90 per cent. purification on its liquid portion. At what rate of flow must the liquor be treated?

The average figures of analysis are given as

Ammoniacal nitrogen - - - - -	5·03
Organic nitrogen - - - - - -	3·34
"Oxygen absorbed" in 4 hours - -	8·67

Applying the formula given on page 210:—

$$(5{\cdot}03 + 3{\cdot}34) \times 4{\cdot}5 + 8{\cdot}67 \times 6{\cdot}5 = 94{\cdot}01.$$

The time of contact necessary to effect 90% purification on a liquor of strength 57 is 1·5 hours, as given by the curve in Diagram 1.

For a liquor of strength 94 the time will therefore be

$$\frac{1{\cdot}5 \times 94}{57} = 2{\cdot}4 \text{ hours.}$$

From the curve for coarse material in Diagram 2, the rate at which the liquor must be filtered to give 2·4 hours contact is 130 gallons per cube yard per day.

Example 2.

A very good precipitation liquor, containing only 2 to 3 parts per 100,000 of suspended matter, is required to yield an effluent showing 100% purification after filtration through material, graduated from very fine (sand) to coarse. The strength of the liquor is 50. At what rate per cube yard must the liquor be treated?

From Diagram 1, 100% purification required 2·4 hours for strength 57.

$$\therefore \text{ Contact for strength } 50 = \frac{2{\cdot}4 \times 50}{57} = 2{\cdot}1 \text{ hours.}$$

If the curve for fine material in Diagram 2 is taken as a guide, it will be seen that the liquor could pass through the clean filters at as high a rate as 500 gallons per cube yard, and give at least 2·1 hours contact.

With a material so fine as sand, however good the precipitation liquor may be, choking will be rapid at such a high rate of flow, and the filter will have to be washed at frequent intervals.

Example 1 is actually the Accrington works filter effluent, as given in the tables of analytical results on pages 125 and 133 of the Fifth Report of the Commission.

The working rate was 140 gallons per cube yard, yielding 92% purification on the effluent without suspended solids.

Example 2 represents the method in use at Chorley, where the filters effected 100% purification when worked at the rate of 525 gallons per cube yard.

Although the experiments which suggested this method of calculating the rate of filtration suitable in different cases were made with precipitation liquor only, the table given below shows that all the ordinary types of sewage liquor can be dealt with on these lines. Even sewages such as those of Leeds and Birmingham, which contain large proportions of trade waste, are amenable to the method; but in these cases the purification effected will generally be lower than with a sewage that is mainly domestic.

The following table* gives the percentage purification which the percolating filters at several places ought to effect theoretically, if they had originally been designed by the "time of contact" method, compared with the percentage purification which they actually do effect, as shown by the figures of analysis.

Place.	Type of Liquor.	Strength of Liquor.	Size of filtering Material.	Rate of Filtration in gallons per cube yard per 24 hours.	Percentage Purification.		Remarks.
					Indicated.	Actual.	
Leeds - - - -	Crude sewage.	123	Very coarse.	52	**98**	96	
" - - - -	" "	173	$\frac{3}{8}$ in. to $\frac{5}{8}$ in.	25	**100 + 6**	over 100 + 1	Ducat filter.
Dorking Experimental -	Settled sewage.	80	2 ins. to 4 ins.	120	**96**	99	
Accrington Works - -	Septic tank liquor.	94	" "	140	**88**	92	
Accrington Experimental I.	Septic tank liquor, strong.	85	2 ins. to 3 ins.†	100	**96**	98	
" "	Septic tank liquor, weak.	48	" "	200	**96**	96	
" II.	Septic tank liquor, strong.	81	" "	100	**97**	100 + 8	
" "	Septic tank liquor, weak.	41	" "	100	**100 + 10**	100 + 8	
" III.	Septic tank liquor, strong.	73	" "	125	**96**	100 + 3	
" "	Septic tank liquor, weak.	40	" "	250	**96**	100 + 3	
Birmingham - - -	Septic tank liquor	113	Coarse.	83	**92**	92	
Guildford - - -	" " "	90	Over 2 ins.	50	**100 + 8**	100 + 10	
Hanley } Dr. Reid's experiments on one filter at various depths.	" " "	32	$\frac{1}{8}$ inch.	600	**100 + 13**	100 + 14	1 ft. deep.
"	" " "	32	"	400	**100 + 14**	100 + 16	2 "
"	" " "	32	"	200	**100 + 17**	100 + 16	3 "
"	" " "	32	"	133	**100 + 20**	100 + 15	4·5 "
Leeds - - - -	" " "	76	Over $1\frac{1}{2}$ ins.	63	**100 + 6**	100 + 1	
Dorking Experimental -	Limed septic liquor	68	2 ins. to 4 ins.	211	**90**	92	
"	" " "	62	" "	350	**85**	86	
Chorley - - - -	Precipitation liquor	50	Very fine to coarse.	525	**100 + 4**	100	
Rochdale - - - -	" "	39	Over $1\frac{1}{2}$ ins.	157	**100 + 6**	100 + 8	

It will be noticed that the greatest differences between the indicated and the actual purification occur in the experimental filters at Accrington.‡ These results are of special interest, because they illustrate very clearly the effect of suspended matter held up in the filters, as referred to on page 210.

The Accrington septic tank liquor contains a large amount of suspended solid (14—20 parts per 100,000).

* This table is compiled partly from Dr. Reid's evidence (*loc. cit.*), from the memorandum on "Estimation of the Work done by Sewage Filters * * * " in this Appendix, and from the Dorking results.

† With some pieces up to about 4 inches.

‡ The Accrington experiments; this Appendix, p. 52 *et seq.*

In Experiment I. the filters started with clean material, and the experiment lasted 14 months. The indicated and actual purifications are in close agreement, the filter treating strong liquor showing 2 per cent. higher actual purification than that indicated. On studying the detailed analyses of these experiments, it is found that while approximately the same total amount of suspended solid went on to each filter, considerably more solid came out of the filter treating weak liquor, no doubt because of the rate of flow being twice as high as on the filter treating strong liquor. It follows that when Experiment II. began, the strong liquor filter was giving a longer contact than the weak liquor filter, at an equal flow of 100 gallons per cube yard on each. The effect of this is seen in the high percentage purification of 100+8 per cent., actually effected on the strong liquor, instead of the 97 per cent. indicated. During this experiment the solids came out from both filters at about the same rate, so that the state of the filters remained as before.

In Experiment III. the usual "spring out-flush" of solids occurred, which appears to have brought the filters into line again as regards the contacts afforded, for the purifications actually effected are now equal, but both are 7 per cent. higher than the indicated. This difference is a measure of the amount of solid held up in the filter after two years' continuous work.

While the Dorking experiments on the deep and shallow filters were in progress, a highly instructive paper by Mr. W. Clifford,* Chemist and Manager at the Wolverhampton Sewage Works, on the time of percolation for filter beds, was published, in which he describes various laboratory experiments made with small filters (18 inches in diameter), filled with various grades of different filtering media. The experiments were all made with clean material and distilled water; no sewage liquid was used, as "the difficulties of investigating the water contents of a working filter bed seemed insuperable." No data for material of over 1¼ inch grade are recorded in the paper, but for fine breeze (⅜—⅛ inch) the time of percolation, when sprinkled at the rate of 100 gallons per cube yard per day, is given as about 6 hours. On refering to the curve for fine material (⅛ to ½ inch clinker) in Diagram 2, the time of contact for 100 gallons per cube yard is found to be exactly 6 hours. Similarly, Mr. Clifford gives 185 minutes as the time of percolation for 200 gallons per cube yard on ⅜ to ⅛ inch clinker; the curve for fine material shows 3·1 hours for the working filters. Under the uniform conditions of the laboratory the times of percolation can be determined with much greater precision than is possible with filters actually treating sewage in the open, so that this agreement is a welcome confirmation of the Dorking results.

The method described in this section of the report is an attempt to show how the design of percolating filter installations may be made a more exact operation than it is at present. The close agreement between the purification indicated and that actually obtained at a number of places, under varied conditions of working, is evidence that the observations on which the method is based are not due to mere coincidence. It encourages the hope that by further investigation on similar lines, sewage purification may be standardised to a greater extent than has hitherto seemed possible.

May, 1909.

ERIC H. RICHARDS.

PART V.—RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF SAMPLES OF SEWAGES, EFFLUENTS, ETC., COLLECTED AT DORKING SEWAGE WORKS. By Dr. A. C. Houston.

SECTION I.—*Comparison between settled sewage, precipitation liquor, and septic tank liquor, and the effluents from filters treating these liquids, separately.*

SECTION II.—*Comparison between the combined filter effluent (after settlement) before, and after, passing through a sand filter.*

SECTION III.—*Some experiments on the action of chloros (sodium hypochlorite) as regards the sterilisation of filter effluents.*

SECTION IV.—*Comparison between the effluents from coarse shallow and coarse deep filters; and fine shallow and fine deep filters, all treating precipitation liquor.*

SECTION I.—*Comparison between settled sewage, precipitation liquor, and septic tank liquor and the effluents from filters treating these liquids separately.*

The results are given in detail in Tables 1, 2, and 3.

The chief results may be summarised as follows:

*Average total number of bacteria per c.c.**

Raw Liquors.		Effluents.	
Settled sewage - - - -	27,322,222	7,398,888	Effluent from filter treating settled sewage.
Precipitation liquor - - -	18,744,444	3,060,000	Effluent from filter treating precipitation liquor.
Septic tank liquor - - -	17,111,111	2,025,000	Effluent from filter treating septic tank liquor.

* The individual results varied so greatly that the average figures must be read with discretion.

It will be seen that the precipitation and septic tank liquors and their respective effluents contained fewer bacteria than the settled sewage and its filter effluent.

B. Coli results per c.c.

Raw Liquors.		Effluents.	
Settled Sewage.	Variable results but usually one million.	Variable results but usually from 10,000 to 100,000.	Effluent from filter treating settled sewage.
Precipitation Liquor.	Variable results but usually from 100,000 to one million.	Variable results but usually from 10,000 to 100,000.	Effluent from filter treating precipitation liquor.
Septic Tank Liquor.	Variable results but usually one million.	Variable results but usually about 10,000.	Effluent from filter treating septic tank liquor.

The differences between each of the three *raw* liquors and each of the three filter effluents were not so well marked as to call for any special comment. Speaking generally, the raw liquors contained about one million and the filter effluents about 10,000 to 100,000 B. coli (or coli-like microbes) per c.c.

B. Enteritidis Sporogenes test per c.c.

Raw Liquors.		Effluents.	
Settled Sewage.	Variable results but usually about 100.	Variable results but usually about 10.	Effluent from filter treating settled sewage.
Precipitation Liquor.	Variable results but usually about 10 to 100.	Variable results but usually about 10.	Effluent from filter treating precipitation liquor
Septic Tank Liquor.	Variable results but usually about 100.	Variable results but usually about 10 to 100.	Effluent from filter treating septic tank liquor.

* "On Percolation Beds," W. Clifford, Proc. Inst. Civil Eng., Vol. 172, ii.

The *raw* liquors yielded about the same results and the filter effluents were also fairly comparable. The filtration treatment reduced, but not to a very material extent, the spores of this anaerobe.

Dealing with the results collectively :—

(1) Judging from the foregoing results, precipitation liquor and septic tank liquor are, on the whole, somewhat less impure (bacteriologically) than settled sewage.

(2) Filters dealing with precipitation liquor and septic tank liquor yield possibly slightly better results (bacteriologically) than does a filter treating settled sewage. But the points of difference were so slight as to render it seemingly a matter of comparative indifference, from the bacteriological point of view, which kind of *raw* liquor a filter bed is called upon to treat. That is, so far as can be judged by the results shewn in Tables 1, 2, and 3.

(3) Although the effluents from the filters dealing with settled sewage, precipitation liquor, and septic tank liquor, respectively, were, from the point of view of percentage purification, considerably less impure than the raw liquors, antecedent to treatment, the number of bacteria still remaining in the effluents was very large.

SECTION II.—*Comparison between the combined filter effluent (after settlement) before, and after, passing through a sand filter.*

The results are given in detail in Table 4.

The chief results may be summarised as follows :—

	Total number of bacteria per c.c.	B. Coli test per c.c.	B. Enteritidis Sporogenes test per c.c.
Effluent *before* sand filtration.	2,912,000.	Variable results but usually 10,000 to 100,000.	Variable results but usually about 10.
The same *after* sand filtration.	108,466 (96% reduction).	Variable results but usually about 1,000 to 10,000.	Variable results but usually about 1.

It will be seen that the sand filtration process reduced the number of bacteria 96 per cent.

The results, therefore, were very satisfactory from the point of view of percentage reduction.

On the other hand, the number of bacteria still remaining in the sand-filtered effluent was so great, that the liquid could only be regarded as most impure bacteriologically.

Apart from questions of relative cost, sand filtration of a sewage effluent compares unfavourably, in my opinion, with sterilisation as a final process of bacteriological purification.

Briefly stated, it was found at Dorking that about 1 part of chloros to 25,000 parts of effluent, acting for about ten hours, was sufficient for sterilisation purposes, as judged by the absence of B. Coli from 1 c.c. of the liquid, after treatment.

I believe, however, that about 1 part of chloros to 100,000 parts of effluent would suffice for sterilisation purposes in the case of a sewage effluent of slightly better quality than the Dorking effluent, and one containing less oxidisable suspended matter.

In view of the statements contained in my other report on sterilisation it appears unnecessary to enter into further detail.

SECTION III.—*Some experiments on the action of chloros (sodium hypochlorite) as regards the sterilisation of effluents.*

These experiments were undertaken in confirmation of the results obtained some years previously at Hendon, described in a separate report in this Appendix.

SECTION IV.—*Comparison between the effluents from coarse shallow, and course deep filters ; and fine shallow, and fine deep filters, all treating precipitation liquor.* *

The results are shewn in detail, in Tables 5, 6, 7 and 8.

The following is a brief summary of the chief results:

Average number of Bacteria per c.c.

Precipitation Liquor.	Effluent from Coarse Shallow Filter.	Effluent from Coarse Deep Filter.	Effluent from Fine Shallow Filter.	Effluent from Fine Deep Filter.
<u>6,904,411</u>	<u>857,897</u>	<u>407,015</u>	<u>377,535</u>	<u>58,585</u>
(3,190,191)	(224,669)	(108,167)	(79,143)	(21,439)

N.B.—The underlined figures refer to the number of microbes as counted on gelatine plates on the 3rd day at 20-22°C. The figures in brackets refer to the number of microbes as counted on Agar plates on the 2nd day at 37°C.

B. Enteriditis Sporogenes test per c.c.

Precipitation Liquor.	Effluent from Coarse Shallow Filter.	Effluent from Coarse Deep Filter.	Effluent from Fine Shallow Filter.	Effluent from Fine Deep Filter.
Variable results, but usually from about 10 to 100.	Variable results, but usually about 10.	Variable results, but usually from about 1 to 10.	Variable results, but usually about 1.	Variable results, but usually either none (in 1 c.c.) or 1.

B. Coli test per c.c.

Precipitation Liquor.	Effluent from Coarse Shallow Filter.	Effluent from Coarse Deep Filter.	Effluent from Fine Shallow Filter.	Effluent from Fine Deep Filter.
Variable results, usually about 100,000.	Variable results, usually from 1,000 to 10,000, most often the latter.	Variable results, usually from 1,000 to 10,000, most often the former.	Variable results, usually from 1,000 to 10,000 most often 1,000 (or less).	Variable results, usually from about 100 to 1,000.

In summary of these results it is of interest to note :—

(1) That the deep coarse and the deep fine filters yielded better results than the shallow coarse and the shallow fine filters respectively.

(2) That the fine filters yielded better results than the coarse filters.

(3) That the shallow fine filter yielded better results than the deep coarse filter.

It would thus appear that, from the bacteriological point of view, "fineness" of material is of primary importance, but that depth of material (whether fine or coarse) has a quite appreciable bearing on the results obtained.

The bacteriological analysis set forth in Tables 1-8 were most carefully carried out by Miss Hartley.

*The words shallow and deep refer to the depth of the filtering material, and the words coarse and fine to the *size* of the material.

TABLE 1.

SHOWING THE RESULTS OF A COMPARISON BETWEEN SETTLED SEWAGE AND ITS CORRESPONDING EFFLUENT.

Description of the Sample.	Total Number of Microbes per c.c. (Gelatine at 20°C.)	B. Coli or Coli-like Microbes per c.c.	B. Enteritidis Sporogenes per c.c.	Description of the Sample.	Total number of Microbes per c.c. (Gelatine at 20° C.)	°/o reduction.	B. Coli or Coli-like Microbes per c.c.	B. Enteritidis Sporogenes per c.c.
125. Settled sewage, April 29th, 1906 -	4,300,000	1,000,000	100	128. Effluent from filter receiving settled sewage, April 29th, 1906 -	3,200,000	26	10,000	10
133. Settled sewage, May 14th, 1906 -	20,000,000	1,000,000	1,000	136. Effluent from filter receiving settled sewage, May 14th, 1906 -	1,280,000	94	10,000	100
142. Settled sewage, May 22nd, 1906 -	35,000,000	1,000,000	100	145. Effluent from filter receiving settled sewage, May 22nd, 1906 -	9,900,000	92	100,000	10
150. Settled sewage, May 31st, 1906 -	50,000,000	1,000,000	100	153. Effluent from filter receiving settled sewage, May 31st, 1906 -	10,800,000	78	100,000	1,000
159, Settled sewage, June 8th, 1906 -	39,000,000	1,000,000	100	162. Effluent from filter receiving settled sewage, June 8th, 1906 -	31,000,000	20	1,000,000	100
168. Settled sewage, June 16th, 1906 -	26,000,000	1,000,000	10	171. Effluent from filter receiving settled sewage, June 16th, 1906 -	6,100,000	76	1,000,000	10
176. Settled sewage, June 24th, 1906 -	14,000,000	1,000,000	1.000	179. Effluent from filter receiving settled sewage, June 24th, 1906 -	13,000,000	7	10,000	100
185. Settled sewage, July 2nd, 1906 -	24,000,000	10,000,000	100	188. Effluent from filter receiving settled sewage, July 2nd, 1906 -	4,300,000	82	10,000	1
192. Settled sewage, July 11th, 1906 -	78,000,000	10,000,000	10	195. Effluent from filter receiving settled sewage, July 11th, 1906 -	18,000,000	77	10,000	10
201. Settled sewage, July 19th, 1906 -	33,000,000	1,000,000	100	204. Effluent from filter receiving settled sewage, July 19th, 1906 -	2,300,000	93	100,000	10
208. Settled sewage, July 27th, 1906 -	35,000,000	1,000,000	100	211. Effluent from filter receiving settled sewage, July 27th, 1906 -	2,000,000	94	100,000	10
225. Settled sewage, August 12th, 1906 -	14,000,000	1,000,000	10	228. Effluent from filter receiving settled sewage, August 12th, 1906 -	1.000,000	93	10,000	10
234. Settled sewage, August 20th, 1906 -	21,000,000	1,000,000	10	237. Effluent from filter receiving settled sewage, August 20th, 1906 -	11,000,000	48	10,000	10
283. Settled sewage, October 9th, 1906 -	12,000.000	1,000,000	100	285. Effluent from filter receiving settled sewage, October 9th, 1906 -	2,000,000	83	100,000	1
291. Settled sewage, October 17th, 1906	10,000,000	1,000,000	100	294. Effluent from filter receiving settled sewage, October 17th, 1906 -	2,000,000	80	10,000	1
299. Settled sewage, October 25th, 1906	38,000,000	1,000,000	100	302. Effluent from filter receiving settled sewage, October 25th, 1906 -	2,000,000	94	10,000	10
307. Settled sewage, November 2nd, 1906	22,500,000	1,000,000	1,000	310. Effluent from filter receiving settled sewage, November 2nd, 1906	9,400,000	58	100.000	100
315. Settled sewage, November 10th,1906	16,000,000	1,000,000	100	318. Effluent from filter receiving settled sewage, November 10th, 1906	3,900,000	75	100,000	100

TABLE 2.

SHOWING THE RESULTS OF A COMPARISON BETWEEN PRECIPITATION LIQUOR AND ITS CORRESPONDING EFFLUENT.

Description of the sample.	Total Number of Microbes per c.c. (Gelatine at 20°C.	B. Coli or Coli-like Microbes per c.c.	B. Enteritidis Sporogenes per c.c.	Description of the Sample.	Total Number of Microbes per c.c. (Gelatine at 20°C)	% re uc- t on.	B. Coli or Coli-like Microbes per c.c.	B. Enteritidi Sporogenes per c.c.
126. Precipitation liquor, April 29th, 1906	1,200,000	10,000	10	129. Effluent from filter receiving precipitation liquor, April 29th, 1906	670,000	44	1,000	1
134. Precipitation liquor, May 14th, 1906	18,800,000	1,000,000	1,000	137. Effluent from filter receiving precipitation liquor, May 14th, 1906	2,880,000	85	100,000	10
143. Precipitation liquor, May 22nd, 1906	11,000,000	100,000	10	146. Effluent from filter receiving precipitation liquor, May 22nd, 1906	2,680,000	76	100,000	10
151. Precipitation liquor, May 31st, 1906	33,000,000	100,000	100	154. Effluent from filter receiving precipitation liquor, May 31st, 1906	13,200,000	60	10,000	100
160. Precipitation liquor, June 8th, 1906	38,000,000	100,000	100	163. Effluent from filter receiving precipitation liquor, June 8th, 1906	2,900,000	92	100,000	10
169. Precipitation liquor, June 16th, 1906	25,000,000	100,000	10	172. Effluent from filter receiving precipitation liquor, June 16th, 1906	1,350,000	95	100,000	10
177. Precipitation liquor, June 24th, 1906	15,000,000	1,000,000	100	180. Effluent from filter receiving precipitation liquor, June 24th, 1906	500,000	96	100,000	100
186. Precipitation liquor, July 2nd, 1906	23,000,000	100,000	10	182. Effluent from filter receiving precipitation liquor, July 2nd, 1906	2,200,000	90	10,000	10
193. Precipitation liquor, July 11th, 1806	41,000,000	1,000,000	100	195. Effluent from filter receiving precipitation liquor, July 11th, 1906	17,000,000	58	100,000	10
202. Precipitation liquor, July 19th, 1906	19,000,000	10,000	10	205. Effluent from filter receiving precipitation liquor, July 19th, 1906	1,200,000	94	100,000	10
209. Precipitation liquor, July 27th, 1906	10,000,000	1,000,000	10	212. Effluent from filter receiving precipitation liquor, July 27th, 1906	1,200,000	88	10,000	10
226. Precipitation liquor, Aug. 12th, 1906	16,000,000	1,000,000	100	229. Effluent from filter receiving precipitation liquor, Aug. 12th, 1906	1,900,000	88	100,000	10
235. Precipitation liquor, Aug. 20th, 1906	23,000,000	100,000	10	238. Effluent from filter receiving precipitation liquor, Aug. 20th, 1906	2,100,000	90	10,000	10
283. Precipitation liquor, Oct. 9th, 1906	11,000,000	100,000	10	286. Effluent from filter receiving precipitation liquor, Oct. 9th, 1906	600,000	94	10,000	10
292. Precipitation liquor, Oct. 17th, 1906	7,000,000	1,000,000	10	295. Effluent from filter receiving precipitation liquor, Oct. 17th, 1906	200,000	97	10,000	1
300. Precipitation liquor, Oct. 25th, 1906	18,000,000	100,000	100	303. Effluent from filter receiving precipitation liquor, Oct. 25th, 1906	1,500,000	91	10,000	10
308. Precipitation liquor, Nov. 2nd, 1906	14,400,000	100,000	10	311. Effluent from filter receiving precipitation liquor, Nov. 2nd, 1906	2,500,000	82	100,000	10
316. Precipitation liquor, Nov. 10th, 1906	13,000,000	100,000	10	319. Effluent from filter receiving precipitation liquor, Nov. 16th. 1906	500,000	96	1,000	10

TABLE 3.

SHOWING THE RESULTS OF A COMPARISON BETWEEN SEPTIC TANK LIQUOR AND ITS CORRESPONDING EFFLUENT.

Description of the Sample.	Total Number of Microbes per c. c. (Gelatine at 20°C.)	B. Coli or Coli-like Microbes per c. c.	B. Enteritidis Sporogenes per c.c.	Description of the Sample.	Total Number of Microbes per c.c. (Gelatine at 20°C.)	% reduction.	B. Coli or Coli-like Microbes per c.c.	B. Enteritidis Sporogenes per c.c.
127. Septic tank liquor, April 29th, 1906	3,400,000	10,000	100	130. Effluent from filter receiving septic tank liquor, April 29th, 1906 -	690,000	79	10,000	10
135. Septic tank liquor, May 14th, 1906 -	9,600,000	1,000,000	100	138. Effluent from filter receiving septic tank liquor, May 14th, 1906 -	770,000	92	10,000	100
144. Septic tank liquor, May 22nd, 1906-	17,000,000	1,000,000	100	147. Effluent from filter receiving septic tank liquor, May 22nd, 1906 -	11,400,000	33	100,000	100
152. Septic tank liquor, May 31st, 1906 -	39,000,000	1,000,000	1000	155. Effluent from filter receiving septic tank liquor, May 31st, 1906 -	8,000,000	79	100,000	100
161. Septic tank liquor, June 8th, 1906 -	36,000,000	1,000,000	10	164. Effluent from filter receiving septic tank liquor, June 8th, 1906 -	2,100,000	94	100,000	100
170. Septic tank liquor, June 16th, 1906	7,000,000	1,000,000	100	173. Effluent from filter receiving septic tank liquor, June 16th, 1906 -	410,000	94	10,000	10
178. Septic tank liquor, June 24th, 1906-	12,000,000	1,000,000	100	181. Effluent from filter receiving septic tank liquor, June 24th, 1906 -	540,000	95	10,000	100
187. Septic tank liquor, July 2nd, 1906 -	11,000,000	1,000,000	100	190. Effluent from filter receiving septic tank liquor, July 2nd, 1906 -	1,600,000	85	1,000	10
194. Septic tank liquor, July 11th, 1906 -	35,000,000	1,000,000	100	197. Effluent from filter receiving septic tank liquor, July 11th, 1906 -	1,200,000	96	10,000	100
203. Septic tank liquor, July 19th, 1906 -	13,000,000	1,000,000	100	206. Effluent from filter receiving septic tank liquor, July 19th, 1906 -	1,000,000	92	10,000	10
210. Septic tank liquor, July 27th, 1906 -	8,000,000	1,000,000	10	213. Effluent from filter receiving septic tank liquor, July 27th, 1906 -	1,500,000	81	10,000	10
227. Septic tank liquor, Aug. 12th, 1906-	20,000,000	1,000,000	100	230. Effluent from filter receiving septic tank liquor, Aug. 12th, 1906 -	1,400,000	93	10,000	100
236. Septic tank liquor, Aug. 20th, 1906-	16,000,000	1,000,000	10	239. Effluent from filter receiving septic tank liquor, Aug. 20th, 1906 -	1,900,000	88	10,000	100
284. Septic tank liquor, Oct. 9th, 1906 -	27,000,000	100,000	10	287. Effluent from filter receiving septic tank liquor, Oct. 9th, 1906 -	1,200,000	95	10,000	10
293. Septic tank liquor, Oct. 17th, 1906 -	19,000,000	1,000,000	10	296. Effluent from filter receiving septic tank liquor, Oct. 17th, 1906 -	500,000	97	1,000	10
301. Septic tank liquor, Oct. 25th, 1906 -	14,000,000	100,000	1000	304. Effluent from filter receiving septic tank liquor, Oct. 25th, 1906 -	410,000	97	10,000	10
309. Septic tank liquor, Nov. 2nd, 1906 -	13,000,000	100,000	100	312. Effluent from filter receiving septic tank liquor, Nov. 2nd, 1906 -	1,230,000	90	1,000	10
317. Septic tank liquor, Nov. 10th, 1906	8,000,000	10,000	100	320. Effluent from filter receiving septic tank liquor, Nov. 10th, 1906 -	600,000	92	10,000	10

TABLE 4

Showing the Results of a Comparison between a Combined Settled Effluent before and after Sand Filtration.

Description of Sample.	Total number of Microbes per c. c. (Gelatine at 20°C.)	B. Coli or Coli-like microbes per c. c.	B. Enteritidis Sporogenes per c.c.	Description of Sample.	Total number of Microbes per c. c. (Gelatine at 20°C.)	% reduction.	B. Coli or Coli-like microbes per c. c.	B. Enteritidis Sporogenes per c. c.
131. Combined settled effluent going on to sand filter, April 29th, 1906	790,000	1,000	10	132. Effluent from sand filter, April 29th, 1906	40,000	95	100	1
139. Combined settled effluent going on to sand filter, May, 14th, 1906	1,150,000	10,000	10	140. Effluent from sand filter, May 14th, 1906	130,000	88	1,000	1
148. Combined settled effluent going on to sand filter, May 22nd, 1906	12,000,000	100,000	10	149. Effluent from sand filter, May 22nd, 1906	490,000	96	10,000	1
156. Combined settled effluent going on to sand filter, May 31st, 1906	3,300,000	100,000	100	157. Effluent from sand filter, May 31st, 1906	90,000	97	100	10
165. Combined settled effluent going on to sand filter, June 8th, 1906	9,800,000	100,000	10	166. Effluent from sand filter, June 8th, 1906	190,000	98	1,000	1
174. Combined settled effluent going on to sand filter, June 16th, 1906	510,000	10,000	10	175. Effluent from sand filter, June 16th, 1906	50,000	90	1,000	1
182. Combined settled effluent going on to sand filter, June 24th, 1906	130,000	1,000	10	183. Effluent from sand filter, June 24th, 1906	7,000	95	1,000	1
191. Combined settled effluent going on to sand filter, July 2nd, 1906	1,500,000	1,000	10	192. Effluent from sand filter, July 2nd, 1906	130,000	91	100	1
198. Combined settled effluent going on to sand filter, July 11th, 1906	6,800,0000	100,000	1	199. Effluent from sand filter, July 11th, 1906	140,000	98	10,000	1
207. Combined settled effluent going on to sand filter, July 19th, 1906	2,300,000	10,000	10	208. Effluent from sand filter, July 19th, 1906	32,000	98	1,000	1
214. Combined settled effluent going on to sand filter, July 27th, 1906	1,800,000	100,000	1	215. Effluent from sand filter, July 27th, 1906	46,000	97	1,000	1
231. Combined settled effluent going on to sand filter, Aug. 12th, 1906	800,000	10,000	1	232. Effluent from sand filter, Aug. 12th, 1906	11,000	98	1,000	Less than 1
240. Combined settled effluent going on to sand filter, Aug. 20th, 1906	1,300,000	10,000	10	241. Effluent from sand filter, Aug. 20th, 1906	36,000	97	1.000	Less than 1
288. Combined settled effluent going on to sand filter, Oct. 9th, 1906 -	1,300,000	10,000	10	289. Effluent from sand filter, Oct. 9th, 1906	178,000	86	100	1
297. Combined settled effluent going on to sand filter, Oct. 17th, 1906	200,000	100,000	10	298. Effluent from sand filter, Oct. 17th, 1906	57,000	71	100	1

TABLE 5

Showing the Results of a comparison between the Effluents from Coarse Shallow and Coarse Deep Filters; and Fine Shallow and Fine Deep Filters, all treating Precipitation Liquor. Number of Bacteria per c.c. Gelatine at 20° C.

—	Precipitation Liquor.	Effluent from Coarse Shallow Filter.	Effluent from Coarse Deep Filter.	Effluent from Fine Shallow Filter.	Effluent from Fine Deep Filter.
Dorking, July 24th, 1907 -	7,900,000	630,000	210,000	53,000	38,000
,, ,, 29th, ,, -	5,600,000	124,000	62,000	100,000	56,000
,, August 6th, ,, -	7,400,000	860,000	270,000	340,000	54,000
,, ,, 12th, ,, -	11,000,000	710,000	280,000	240,000	170,000
,, ,, 20th, ,, -	16,000,000	1,200,000	840,000	410,000	280,000
, October 14th, ,, -	14 000,000	1 800,000	320,000	210,000	120,000
,, ,, 17th, ,, -	16,000,000	800,000	410,000	190 000	25,000
,, ,, 21st ,, -	15,000,000	970,000	110,000	125,000	21,000
,, ,, 24th, ,, -	18,000,000	3 200,000	970,000	650,000	230,000
,, ,, 30th, ,, -	15,000,000	580,000	340,000	212,000	62,000
,, November 1st, ,, -	10,000,000	950,000	340,000	690,000	8,000
,, ,, 4th, ,, -	13,000,000	720,000	520,000	82,000	10,600
,, ,, 7th, ,, -	19,000,000	3,200,000	950,000	810,000	310,000
,, ,, 11th, ,, -	10,000,000	810,000	610,000	230,000	53,000
,, ,, 14th, ,, -	18,000,000	1,490,000	940,000	590,000	204,000
,, ,, 18th, ,, -	9,300,000	660,000	420,000	490,000	38,000
,, ,, 21st, ,, -	12,900,000	1,580,000	2,350,000	1,280,000	98,000
,, ,, 25th, ,, -	3,000,000	300,000	110,000	480,000	18,000
,, ,, 28th, ,, -	14,800,000	510,000	87,000	760,000	40,000
,, December 2nd, ,, -	8,000,000	220,000	340,000	720,000	48,000
,, ,, 5th, ,, -	15,000,000	2,040,000	1,960,000	520,000	148,000
,, ,, 9th, ,, -	4,000,000	620,000	530,000	230,000	144,000
,, ,, 12th, ,, -	8,400,000	650,000	510,000	400,000	190,000
,, ,, 16th, ,, -	4,200,000	690,000	310,000	580,000	93,000
,, ,, 19th, ,, -	18,900,000	2,840,000	1,710,000	2,089,000	296,000
,, January 6th, 1908 -	4,100,000	610,000	490,000	310,000	57,000
,, ,, 10th, ,, -	1,900,000	120,000	100,000	110,000	41,000
,, ,, 13th, ,, -	3,300,000	320,000	368,000	92,000	71,000
,, ,, 16th, ,, -	4,400,000	310,000	240,000	910,000	223,000
,, ,, 20th, ,, -	3,600,000	950,000	120,000	180,000	14,000
,, February 20th, ,, -	6,100,000	460,000	320,000	560,000	95,000
,, ,, 24th, ,, -	3,900,000	420,000	250,000	280,000	52,000
,, ,, 27th, ,, -	2,200,000	280,000	190,000	320,000	62,000
,, March 2nd, ,, -	2,600,000	270,000	390,000	270,000	77,000
,, ,, 5th, ,, -	4,200,000	200,000	180,000	90,000	59,000
,, ,, 9th, ,, -	6,000,000	90,000	40,000	35,000	29,000
,, ,, 12th, ,, -	1,100,000	260,000	157,000	195,000	12,100
,, ,, 16th, ,, -	2,300,000	180,000	61,000	165,000	15,000
,, ,, 19th, ,, -	1,000,000	213,000	128,000	40,000	19,000
,, ,, 23rd, ,, -	700,000	110,000	36,000	12,000	4,000
,, ,, 26th, ,, -	1,400,000	110,000	82,000	28,800	20,800
,, ,, 30th, ,, -	4,300,000	450,000	340,000	223,000	109,000
,, April 2nd, ,, -	5,200,000	140,000	70,000	424,000	120,000
,, ,, 6th, ,, -	2,200,000	760,000	204,000	410,000	68,000
,, ,, 9th, ,, -	3,100,000	510,000	185,000	130,000	48,000
,, ,, 13th, ,, -	2,800,000	320,000	94,000	280,000	66,000
,, ,, 23rd, ,, -	6,200,000	240,000	186,000	230,000	45,000
,, ,, 27th, ,, -	2,100,000	140,000	at least 10,000 (all liquefied).	at least 10,000 (all liquefied).	at least 1,000 (all liquefied).
,, ,, 30th, ,, -	13,900,000	220,000	203,000	112,000	135,000
,, May, 4th, ,, -	4,600,000	430,000	260,000	90,000	47,000
,, ,, 7th, ,, -	19,400,000	1,250,000	540,000	267,000	69,000
,, ,, 11th, ,, -	18,900,000	940,000	440,000	1,560,000	621,000
,, ,, 14th, ,, -	15,300,000	380,000	340,000	85,000	90,000
,, ,, 18th, ,, -	10,600,000	460,000	280,000	230,000	120,000
,, ,, 21st, ,, -	2,700,000	410,000	250,000	160,000	112,000
,, June 4th, ,, -	12,200,000	1,020 000	230,000	360,000	79,000
,, ,, 9th, ,, -	7,100,000	3,390,000	270,000	1,080,000	225,000
,, ,, 11th, ,, -	9,300,000	1,540,000	230,000	210,000	20,000
,, ,, 15th, ,, -	11,000,000	1,380,000	580,000	420,000	340,000
,, ,, 18th, ,, -	6,100,000	580,000	330,000	290,000	110,000
,, ,, 22nd, ,, -	4,300,000	320,000	at least 260,000 (overrun with liquefiers)	at least 100,000 (overrun with liquefiers)	at least 100,000 (overrun with liquefiers)
,, ,, 25th, ,, -	9,300,000	1,530,000	310,000	130,000	80,000
,, ,, 29th, ,, -	5,300,000	840,000	390,000	300,000	at least 100,000 (overrun with liquefiers)
,, July 2nd, ,, -	7,100,000	1,600,000	960,000	360,000	230,000
,, ,, 6th, ,, -	11,500,000	3,000,000	540,000	410,000	310,000
,, ,, 9th, ,, -	15,700,000	1,400,000	340,000	260,000	130,000
,, ,, 13th, ,, -	7,200,000	1,280,000	420,000	440,000	290,000
,, ,, 16th, ,, -	8,900,000	750,000	220,000	No Record	170,000

TABLE 6.

SHOWING THE RESULT OF A COMPARISON BETWEEN THE EFFLUENTS FROM COARSE SHALLOW AND COARSE DEEP FILTERS; AND FINE SHALLOW AND FINE DEEP FILTERS; ALL TREATING PRECIPITATION LIQUOR. NUMBER OF BACTERIA PER C.C. AGAR AT 37° C. COUNTED 2nd DAY.

—	Precipitation Liquor.	Effluent from Coarse Shallow Filter.	Effluent from Coarse Deep Filter.	Effluent from Fine Shallow Filter.	Effluent from Fine Deep Filter.
Dorking, July 24th, 1907 -	1,490,000	48,000	10,600	1,300	840
" " 29th, " -	1,570,000	47,000	8,800	31,200	2,970
" August 6th, " -	1,100,000	227,000	85,000	25,000	19,600
" " 12th, " -	5,400,000	240,000	38,000	30,000	23,000
" " 20th, " -	7,600,000	920,000	201,000	17,000	10,000
" October 14th, " -	6,100,000	880,000	83,000	48,000	10,700
" " 17th, " -	5,490,000	320,000	96,000	78,000	12,000
" " 21st, " -	7,400,000	290,000	43,000	56,000	7,100
" " 24th, " -	12,600,000	1,800,000	690,000	415,000	40,000
" " 30th, " -	9,400,000	140,000	106,000	47,000	29,000
" November 1st, " -	7,500,000	380,000	150,000	270,000	2,500
" " 4th, " -	9,100,000	410,000	250,000	21,000	4,900
" " 7th, " -	15,000,000	1,030,000	740,000	460,000	61,000
" " 11th, " -	8,800,000	470,000	410,000	58,000	36,000
" " 14th, " -	8,600,000	630,000	470,000	109,000	68,000
" " 18th, " -	5,100,000	300,000	130,000	52,000	11,000
" " 21st, " -	8,100,000	500,000	1,060,000	680,000	44,000
" " 25th, " -	800,000	90,000	60,000	150,000	9,000
" " 28th, " -	7,200,000	75,000	26,000	70,000	2,000
" December 2nd, " -	5,900,000	41,000	86,900	251,000	9,000
" " 5th, " -	10,000,000	342,000	263,000	78,000	38,000
" " 9th, " -	2,100,000	50,000	40,000	30,000	10,000
" " 12th, " -	1,700,000	40,000	35,000	65,000	20,000
" " 16th, " -	1,320,000	62,000	45,000	69,000	4,800
" " 19th, " -	8,400,000	304,000	119,000	103,000	79,000
" January 6th, " -	1,200,000	220,000	91,000	110,000	32,000
" " 10th, " -	710,000	32,000	38,000	50,000	16,000
" " 13th, " -	860,000	23,000	66,000	21,000	19,900
" " 16th, " -	1,870,000	33,000	29,000	116,000	23,000
" " 20th, " -	640,000	98,000	37,000	31,000	4,000
" February 20th, " -	3,050,000	116,000	73,000	234,000	19,800
" " 24th, " -	630,000	41,000	21,000	38,000	9,000
" " 27th, " -	710,000	39,000	24,000	35,000	6,400
" March 2nd, " -	630,000	56,000	57,000	41,000	18,200
" " 5th, " -	580,000	30,000	26,000	14,000	8 900
" " 9th, " -	260,000	18,000	9,000	7,000	1,200
" " 12th, " -	132,000	15,000	13,300	14,100	1,600
" " 16th, " -	270,000	23,000	6,200	11,000	1,100
" " 19th, " -	620,000	19,300	12,800	21,000	3,000
" " 23rd, " -	80,000	9,000	4,000	7,100	600
" " 26th, " -	101,000	15,000	7,700	4,200	2,650
" " 30th, " -	950,000	120,000	108,000	26,700	18,000
" April 2nd, " -	690,000	67,000	25,000	57,000	34,000
" " 6th, " -	510,000	102,000	81,000	51,000	32,000
" " 9tb, " -	420,000	30,000	22,000	11,000	9,000
" " 13th, " -	530,000	56,000	23,000	52,000	19,000
" " 23rd, " -	440,000	42,000	22,000	19,000	8,600
" " 27th, " -	310,000	10,000	4,000	9,000	1,100
" " 30th, " -	1,130,000	21,000	19,000	12,000	12,500
" May 4th, " -	310,000	25,000	21,000	4,000	3,000
" " 7th, " -	3,060,000	95,000	37,000	23,000	4,800
" " 11th, " -	1,400,000	53,000	58,000	182,000	34,000
" " 14th, " -	2,030,000	27,000	32,000	16,000	11,000
" " 18tb, " -	460,000	142,000	97,000	14,000	11,000
" " 21st, " -	650,000	105,000	28,000	14,000	7,000
" June 4th, " -	4,850,000	134,000	41,000	37,000	13,000
" " 9th, " -	2,460,000	466,000	47,000	153,000	49,000
" " 11th, " -	2,530,000	128,000	51,000	42,000	15,000
" " 15th, " -	2,610,000	311 000	137,000	42,000	66,000
" " 18th, " -	1,220,000	177,000	133,000	21,000	19,000
" " 22nd, " -	1,630,000	101,000	63,000	21,030	13,000
" " 25th, " -	3,570,000	570,000	80,000	48,000	29,000
" " 29th, " -	1,510,000	402,000	147,000	148,000	135,000
" July 2nd, " -	3,870,000	830,000	162,000	132,000	98,000
" " 6th, " -	3,920,000	250,000	45,000	83,000	32,000
" " 9th, " -	1,210,000	320,000	45,000	34,000	30,000
" " 13th, " -	1,620,000	100,000	39,000	82,000	13,000
" " 16th, " -	2,930,000	170,000	28,000	No Record	19,000

TABLE 7.

Showing the results of a comparison between the Effluent from Coarse Shallow and Coarse Deep Filters; and Fine Shallow and Fine Deep Filters; all Treating Precipitation Liquor.

B. Enteritides Sporogenes test per c.c.

—	Precipitation Liquor.	Effluent from Coarse Shallow Filter.	Effluent from Coarse Deep Filter.	Effluent from Fine Shallow Filter.	Effluent from Fine Deep Filter.
Dorking, July 24th, 1907 -	1,000	10	+1 c.c.	neg. 1 c.c.	+1 c.c.
" " 29th, " -	1,000	10	neg. 1 c.c.	+1 c.c.	neg. 1 c.c.
" August 6th, " -	10	10	+1 c.c.	+1 c.c.	neg. 1 c.c.
" " 12th, " -	10	10	+1 c.c.	neg. 1 c.c.	neg. 1 c.c.
" " 20th, " -	10	10	+1 c.c.	neg. 1 c.c.	neg. 1 c.c.
" October 14th, " -	10	10	neg. 1 c.c.	neg. 1 c.c.	neg. 1 e.c.
" " 17th, " -	10	10	+1 c.c.	+1 c.c.	neg. 1 c.c.
" " 21st, " -	10	10	+1 c.c.	neg. 1 c.c.	neg. 1 c.c.
" " 24th, " -	100	10	+1 c.c.	+1 c.c.	+1 c.c.
" " 30th, " -	10	+1 c.c.	+1 c.c.	+1 c.c.	+1 c.c.
" November 1st, " -	10	+1 c.c.	neg. 1 c.c.	neg. 1 c.c.	neg. 1 c.c.
" " 4th, " -	10	10	+1 c.c.	+1 c.c.	neg. 1 c.c.
" " 7th, " -	100	10	10	+1 c.c.	+1 c.c.
" " 11th, " -	10	+1 c.c.	10	+1 c.c.	+1 c.c.
" " 14th, " -	10	+1 c.c.	+1 c.c.	+1 c.c.	+1 c.c.
" " 18th, " -	10	10	10	+1 c.c.	neg. 1 c.c.
" " 21st, " -	10	+1 c.c.	10	10	+1 c.c.
" " 25th, " -	10	+1 c.c.	+1 c.c.	+1 c.c.	neg. 1 c.c.
" " 28th, " -	10	10	10	+1 c.c.	neg. 1 c.c.
" December 2nd, " -	100	10	10	+1 c.c.	neg. 1 c.c.
" " 5th, " -	10	+1 c.c.	+1 c.c.	10	neg. 1 c.c.
" " 9th, " -	100	10	10	10	+1 c.c.
" " 12th, " -	10	+1 c.c.	10	+1 c.c.	neg. 1 c.c.
" " 16th, " -	100	10	10	+1 c.c.	+1 c.c.
" " 19th, " -	10	+1 c.c.	+1 c.c.	+1 c.c.	neg. 1 c.c.
" January 6th, " -	10	10	10	10	+1 c.c.
" " 10th, " -	10	+1 c.c.	+1 c.c.	+1 c.c.	+1 c.c.
" " 13th, " -	10	10	+1 c.c.	+1 c.c.	neg. 1 c.c.
" " 16th, " -	10	+1 c.c.	+1 c.c.	10	+1 c.c.
" " 20th, " -	100	10	10	10	+1 c.c.
" February 20th, " -	10	+1 c.c.	+1 c.c.	neg. 1 c.c.	neg. 1 c.c.
" " 24th, " -	10	+1 c.c.	10	10	+1 c.c.
" " 27th, " -	10	10	neg. 1 c.c.	10	+1 c.c.
" March 2nd, " -	100	10	10	+1 c.c.	+1 c.c.
" " 5th, 1908 -	10	10	10	+1 c.c.	+1 c.c.
" " 9th, " -	10	10	+1 c.c.	+1 c.c.	neg. 1 c.c.
" " 12th, " -	10	10	+1 c.c.	10	+1 c.c.
" " 16th, " -	10	+1 c.c.	+1 c.c.	+1 c.c.	+1 c.c.
" " 19th, " -	+1 c.c.	+1 c.c.	+1 c.c.	neg. 1 c.c.	neg. 1 c.c.
" " 23rd, " -	10	10	+1 c.c.	+1 c.c.	+1 c.c.
" " 26th, " -	+1 c.c.	10	neg. 1 c.c.	+1 c.c.	neg. 1 c.c.
" " 30th, " -	100	10	10	10	+1 c.c.
" April 2nd, " -	10	10	10	10	+1 c.c.
" " 6th, " -	10	10	10	10	10
" " 9th, " -	10	10	10	10	+1 c.c.
" " 13th, " -	100	10	10	10	+1 c.c.
" " 23rd, " -	+1 c.c.	+1 c.c.	+1 c.c.	+1 c.c.	+1 c.c.
" " 27th, " -	10	+1 e.c.	+1 c.c.	+1 c.c.	neg. 1 c.c.
" " 30th, " -	10	10	+1 c.c.	10	+1 c.c.
" May 4th, " -	+1 c.c.	+1 c.c.	+1 c.c.	+1 c.c.	+1 c.c.
" " 7th, " -	10	10	10	10	+1 c.c.
" " 11th, " -	100	10	10	10	+1 c.c.
" " 14th, " -	10	10	+1 c.c.	10	+1 c.c.
" " 18th, " -	+1 c.c.	10	10	10	+1 c.c.
" " 21st, " -	100	10	10	10	+1 c.c.
" June 4th, " -	10	10	10	10	+1 c.c.
" " 9th, " -	10	10	+1 c.c.	10	10
" " 11th, " -	100	10	+1 c.c.	10	+1 c.e.
" " 15th, " -	10	10	10	10	10
" " 18th, " -	10	10	10	10	10
" " 22nd, " -	10	10	+1 c.c.	10	+1 c.c.
" " 25th, " -	+1 c.c.	10	10	+1 c.c.	+1 c.c.
" " 29th, " -	+1 c.c.	10	10	10	10
" July 2nd, " -	10	10	+1 c.c.	10	+1 c.c.
" " 6th, " -	+1 c.c.	10	+1 c.c.	+1 c.c.	+1 c.c.
" " 9th, " -	10	10	10	+1 c.c.	+1 c.c.
" " 13th, " -	10	10	+1 c.c.	+1 c.c.	+1 c.c.
" " 16th, " -	+1 c.c.	10	+1 c.c.	no record	+1 c.c.

TABLE 8.

Showing the results of a comparison between the Effluents from Coarse Shallow and Coarse Deep Filters; and Fine Shallow and Fine Deep Filters, all Treating Precipitation Liquor.

B. Coli test, per c.c.

			Precipitation liquor.	Effluent from Coarse Shallow Filter.	Effluent from Coarse Deep Filter.	Effluent from Fine Shallow Filter.	Effluent from Fine Deep Filter.
Dorking,	July	24th, 1907 -	100,000	10,000	1,000	100	1,000
„	„	29th, „ -	100,000	10,000	1,000	10,000	100
„	August	6th, „ -	100,000	10,000	1,000	1,000	100
„	„	12th, „ -	100,000	10,000	1,000	1,000	100
„	„	20th, „ -	100,000	10,000	1,000	1,000	100
„	October	14th, „ -	1,000,000	100,000	1,000	10,000	1,000
„	„	17th, „ -	100,000	10,000	1,000	10,000	1,000
„	„	21st, „ -	100,000	10,000	1,000	1,000	1,000
„	„	24th, „ -	100,000	10,000	10,000	1,000	100
„	„	30th, „ -	100,000	1,000	100	1,000	1,000
„	November	1st, „ -	100,000	10,000	1,000	1,000	100
„	„	4th, „ -	100,000	10,000	1,000	10,000	1,000
„	„	7th, „ -	1,000,000	10,000	10,000	1,000	1,000
„	„	11th, „ -	100,000	10,000	10,000	10,000	10,000
„	„	14th, „ -	100,000	10,000	10,000	1,000	100
„	„	18th, „ -	100,000	10,000	1,000	10,000	1,000
„	„	21st, „ -	1,000,000	1,000	10,000	1,000	100
„	„	25th, „ -	100,000	1,000	100	1,000	100
„	„	28th, „ -	100,000	1,000	100	1,000	100
„	December	2nd, „ -	100,000	10,000	1,000	10,000	1,000
„	„	5th, „ -	100,000	1,000	1,000	1,000	100
„	„	9th, „ -	100,000	10,000	1,000	1,000	100
„	„	12th, „ -	10,000	1,000	1,000	100	100
„	„	16th, „ -	100,000	1,000	1,000	1,000	10
„	„	19th, „ -	100,000	10,000	1,000	10,000	1,000
„	January	6th, 1908 -	100,000	10,000	10,000	10,000	1,000
„	„	10th, „ -	100,000	10,000	10,000	10,000	100
„	„	13th, „ -	100,000	10,000	10,000	1,000	1,000
„	„	16th, „ -	1,000,000	10,000	1,000	1,000	1,000
„	„	20th, „ -	100,000	10,000	1,000	10,000	10,000
„	February	20th, „ -	100,000	10,000	10,000	1,000	1,000
„	„	24th, „ -	100,000	1,000	10,000	10,000	100
„	„	27th, „ -	10,000	10,000	1,000	10,000	1,000
„	March	2nd, „ -	100,000	1,000	10,000	10,000	10,000
„	„	5th, „ -	100,000	10,000	10,000	100	100
„	„	9th, „ -	10,000	1,000	100	10	10
„	„	12th, „ -	10,000	1,000	100	10	10
„	„	16th, „ -	100,000	1,000	1,000	1,000	100
„	„	19th, „ -	10,000	1,000	1,000	100	100
„	„	23rd, „ -	1,000	1,000	100	100	100
„	„	26th, „ -	1,000	1,000	100	100	100
„	„	30th, „ -	100,000	10,000	10,000	1,000	1,000
„	April	2nd, „ -	10,000	1,000	1,000	10,000	1,000
„	„	6th, „ -	100,000	10,000	10,000	10,000	10,000
„	„	9th, „ -	10,000	10,000	1,000	1,000	1,000
„	„	13th, „ -	10,000	1,000	1,000	10,000	1,000
„	„	23rd, „ -	10.000	1,000	1,000	1,000	100
„	„	27th, „ -	100,000	10,000	100	1,000	100
„	„	30th, „ -	10,000	10,000	10,000	1,000	1,000
„	May	4th, „ -	10,000	1,000	1,000	1,000	100
„	„	7th, „ -	10,000	1,000	1,000	1,000	100
„	„	11th, „ -	100,000	10,000	1,000	10,000	1,000
„	„	14th, „ -	10,000	1,000	1,000	10,000	1,000
„	„	18th, „ -	10,000	1,000	100	1,000	10
„	„	21st, „ -	10,000	1,000	1,000	1,000	100
„	June	4th, „ -	100,000	10,000	10,000	10,000	10,000
„	„	9th, „ -	100,000	10,000	1,000	10,000	10,000
„	„	11th, „ -	1,000,000	10,000	10,000	10,000	1,000
„	„	15th, „ -	100,000	100,000	10,000	1,000	1,000
„	„	18th, „ -	100,000	10,000	10,000	1,000	1,000
„	„	22nd, „ -	100,000	10,000	1,000	1,000	1,000
„	„	25th, „ -	1,000,000	10,000	10,000	1,000	1,000
„	„	29th, „ -	100,000	10,000	1,000	100	1,000
„	July	2nd, „ -	1,000,000	10,000	10,000	10,000	1,000
„	„	6th, „ -	100,000	10,000	10,000	10,000	1,000
„	„	9th, „ -	100,000	1,000	10,000	1,000	1,000
„	„	13th, „ -	1,000,000	1,000	1,000	1,000	1,000
„	„	16th, „ -	100,000	1,000	1,000	No Record.	1,000

A. C. HOUSTON.

MEMORANDUM ON THE COMPARATIVE TREATMENT OF SEPTIC TANK LIQUOR AND PRECIPITATION LIQUOR AT ROCHDALE, BY FILTRATION THROUGH PERCOLATING FILTERS OF COARSE MATERIAL, BY DR. G. McGOWAN AND MR. COLIN C. FRYE.

In the section of Appendix III. to the Fifth Report, which deals with sewage treatment at Rochdale, the purification of septic tank liquor on the large experimental filters there is dealt with at some length, both as regards the septic liquor itself and the filter effluent from it.

It was subsequently thought that, by utilizing these results, an interesting and instructive comparison might be obtained at Rochdale of the treatment by percolating filtration of (a) septic tank liquor and (b) precipitation liquor, both of them from the same sewage—a sewage which contains a large quantity of wool-scouring refuse, etc. The Rochdale Corporation having given their consent to the necessary further work being done, the filters were, from August 3rd, 1906, until January 21st, 1909, made to treat precipitation instead of septic tank liquor.

These filters, as well as the Rochdale septic tank liquor and the filter effluent from it, have been described in Appendix III., p. 448 *et seq.* It need, therefore, only be repeated here that the two large experimental filters in question are of coarse material and are 9 feet deep, and that the liquor is distributed on to them by means of revolving sprinklers.

PERCOLATING FILTRATION OF SEPTIC TANK LIQUOR.

During the observations on the filtration of septic tank liquor, from November, 1902, to November, 1905, the filters were treating at rates of 133 and 150 gallons per cube yard per day (an average of 141 gallons), with the production of excellent and well-oxidized effluents, which contained, however, considerable quantities of suspended solids.

The samples of septic tank liquor examined had the following *average* composition, the figures in brackets indicating the number of samples in each case.*

Parts per 100,000.

Septic Tank Liquor.	Three sets of hourly samples.		Seven chance samples.	
Drawn	May 16th–18th, 1904.		Between November, 1902, and November, 1905.	
Ammoniacal Nitrogen	3·74	(3)	—	
Albuminoid Nitrogen	0·67	(3)	—	
Total Organic Nitrogen	1·27	(3)	—	
Total Nitrogen (by Kjeldahl)	5·01	(3)	4·40	(6)
"Oxygen absorbed" from $\frac{N}{8}$ permanganate at 27° C. *at once*	5·38	(3)	5·12	(7)
"Oxygen absorbed" from $\frac{N}{8}$ permanganate at 27° C. *in 4 hours*	10·92	(3)	10·20	(7)
Chlorine	11·97	(3)	9·69	(4)
Solids in Suspension	5·30	(3)	8·60	(4)
Solids by Centrifuge (vols.)	29·0	(3)	36·0	(7)
Ratio of Solids in Suspension to Centrifuge Solids	1 : 5·5	(3)	1 : 5·6	(4)
Calculated "Strength" †	68·7 (Taking N = 5·0 : Ox. abs. in 4 hrs. = 7·1)		62·1 (Taking N = 4·4 : Ox. abs. in 4 hrs. = 6·5)	

Though less uniform in composition than the hourly samples, the chance samples of septic liquor were on the whole also comparatively even in composition.

For purposes of comparison, the analysis of the hourly and chance samples of precipitation liquor, drawn during the same period as the samples of septic tank liquor, just quoted, may also be given here. At this time all the precipitation liquor at Rochdale was treated upon land and on contact beds.

Parts per 100,000.

Precipitation Liquor.	Three sets of hourly samples.		Four chance samples.	
Drawn	May 16th–18th, 1904.		Between June, 1903 and March, 1905.	
Ammoniacal Nitrogen	4·20	(3)	—	
Albuminoid Nitrogen	0·66	(3)	—	
Total Organic Nitrogen	0·94	(3)	—	
Total Nitrogen (by Kjeldahl)	5·14	(3)	3·48	(3)
"Oxygen absorbed" from $\frac{N}{8}$ permanganate at 27° C. *at once*	6·40	(3)	4·03	(4)
"Oxygen absorbed" from $\frac{N}{8}$ permanganate at 27° C. *in 4 hours*	13·17	(3)	9·69	(4)
Chlorine	13·18	(3)	—	
Solids in suspension	7·80	(3)	—	
Solids by centrifuge (vols.)	23·0	(3)	34·0	(4)
Ratio of solids in suspension to centrifuge solids	1 : 2·9	(3)	—	
Calculated Strength ‡	74·0 (Taking N = 5·1 Ox. abs. in 4 hrs. = 8·5)		—	

* The minimum and maximum figures of analysis are to be found in Appendix III.

† According to the formula :—(Ammon. + Organic N. × 4·5) + (Ox. abs. in 4 hours × 6·5), but allowing for the abnormal ratio here between the figures for "oxygen absorbed" at once and in 4 hours. A ratio of 1 : 3·5 may be taken as being approximately normal.

‡ According to the formula :—(Ammon. + Organic N × 4·5) + (Ox. abs. in 4 hrs. × 6·0), but allowing for the abnormal ratio here between the figures for "Oxygen absorbed" at once and in 4 hours. A ratio of 1 : 4 may be taken as being approximately normal.

Percolating Filter Effluent from Septic Tank Liquor.

The *average* figures of analysis of these filter effluents are as follows. Unfortunately, only the hourly samples of settled, and not also unsettled effluent, were examined, a circumstance for which allowance will have to be made in subsequent comparisons.

Parts per 100,000.

——	Settled Effluent. Three sets of hourly samples.	Settled Effluent. 8 chance samples.	Unsettled Effluent. 5 chance samples.
Drawn	May 16th–18th, 1904.	Between Nov. 1902 and Nov. 1905.	Between Jan. 1903 and Nov. 1905.
Ammoniacal Nitrogen	0·51 (3)	0·06 (2)	0·06 (2)
Albuminoid Nitrogen	0·13 (3)	0·09 (2)	0·10 (2)
Total Organic Nitrogen	0·50 (3)	—	0·25 (2)
Nitrous Nitrogen	0·02 (3)	0·0 ‡(8)	0·0 (5)
Nitric Nitrogen	2·15 (3)	2·2 ap.(8)	3·0 ap.(5)
Total Nitrogen (by Kjeldahl)	3·15 (3)	—	2·68 (2)
"Oxygen absorbed" at 27° C. *at once*	0.50 (3)	0·41 (8)	0·52 (5)
"Oxygen absorbed" at 27° C. *in 4 hours*	1·68 (3)	1·48 (8)	2·16 (5)
Incubator test (by smell)	3 + (3)	7 + (7)	4 + (4)
Dissolved Oxygen taken up from water in 24 hours at 18° C.	—	0·28 (6)	0·32 (5)
Oxygen in solution, when analysed	—	0·6 ap.(6)	0·8 ap.(3)
Chlorine	11·24 (3)	9·02 (4)	8·69 (3)
Solids in suspension	2·2 (3)	4·5 (3)	7·4 (4)
Volatile matter in these solids	1·6 (2)	3·0 (3)	4·5 (4)
Solids by centrifuge (Vols.)	28·8 (3)	44·9 (7)	83·9 (5)
Ratio of solids in suspension to centrifuge solids	1 : 13·1 (2)	1 : 13·4 (3)	1 : 12·4 (4)
Calculated oxidizability* of whole effluent, including the suspended solids and giving credit for the nitrate	4·3	—	—
Calculated oxidizability, excluding suspended solids and giving credit for nitrate	0·7	—	—
Calculated oxidizability, excluding suspended solids and giving no credit for nitrate	4·5	—	—

These effluents have already been discussed in the Rochdale report in Appendix III, and only a few words are therefore required here. The figures of analysis show that the effluents, apart from their suspended solids, were of excellent quality, at least two-thirds of their nitrogen being in the form of nitrate, while they took up (even with their solids) only a comparatively small quantity of dissolved oxygen from water in 24 hours. They were of fairly even composition.

PERCOLATING FILTRATION OF PRECIPITATION LIQUOR.

This was begun in August, 1906, and, excepting for a short interval of about 18 hours, when the necessary connections were being made, there was no break between the filtration of the septic and the precipitation liquors. It may be observed, in passing, that though our first samples were not drawn until nearly two months after the change was made, the effluent from the filtration of precipitation liquor was good from the start. For the first two or three days after the change, it was more opalescent than usual, but this was the only noticeable effect, and it soon passed away; the effluent had throughout a clean earthy smell and it gave no permanent froth upon shaking. It may therefore be taken that, although the immediate effect of the change was to cause a temporary reduction in purification, this reduction was not sufficient to give rise to a bad effluent.

The only noticeable change in the appearance of the filters themselves was in the slimy covering of the uppermost layer of coke. Throughout the filtration of the septic tank liquor this had been greyish-black; with the precipitation liquor it took on a reddish-brown appearance, no doubt because the latter contained much less sulphuretted hydrogen than the septic liquor. At no time during the experiments with precipitation liquor was there any sign of serious ponding on the surface of the filters.

There were, in all, five experiments on the percolating filtration of precipitation liquor, *i.e.*, the liquor was filtered at five different rates, as follows:—

Experiment.	Dates of Experiments.	Duration of Experiment (months).	Rates of filtration in Gallons per cube yard per 24 hours.	Number of samples examined.			
				Precipitation Liquor.	Effluent†. Unsettled.	Settled.	Settled and filtered through paper.
A	Aug. 3rd, 1906—June 13th, 1907.	10½	133	6	7	7	4
A¹	June 14th, 1907—Nov. 6th, 1907.	5	157	2	2	2	2
B	Nov. 7th, 1907—June 4th, 1908.	6	183	9	9	9	9
C	June 5th, 1908—Oct. 15th, 1908.	4½	217	8	8	8	8
D	Oct. 16th, 1908—Jan. 21st, 1909.	3	250	7	7	7	7

Experiment A. August 3rd, 1906—June 13th, 1907.
Rate of Filtration—133 gallons per cube yard per day.

The samples examined during this experiment were drawn between September 29th, 1906, and June 12th, 1907. In this, as in the succeeding experiments, the samples of unsettled effluent correspond with those of precipitation liquor, while those of settled effluent correspond roughly.

* According to the formula:—(Ammon. + Organic N. × 4·5) + (Vol. solids × 2) − (Nitric N. × 3).
† In some sets of samples only a partial analysis was made.
‡ "Ap." = approximately.

The following average figures were obtained on analysis :—

Experiment A. 133 gallons per cube yard. Parts per 100,000.

———	Precipitation liquor.	Unsettled filter effluent.	Settled filter effluent.	
			Original effluent.	Effluent after filtration through paper.
Ammoniacal Nitrogen	2·24 (5)	0·29 (7)	0·35 (5)	0·37 (2)
Albuminoid Nitrogen	0·47 (5)	0·18 (7)	0·14 (5)	0·07 (2)
Total Organic Nitrogen	1·03 (3)	0·45 (4)	—	0·16 (1)
Nitrous Nitrogen	0·06 (3)	0·0 (7)	0·0 (4)	0·0 (1)
Nitric Nitrogen	0·38 (3)	2·02 (7)	2·20 (4)	1·88 (1)
Total Nitrogen (by Kjeldahl)	3·13 (5)	2·78 (4)	2·99 (4)	2·28 (1)
"Oxygen absorbed" at 27° C. *at once*	2·13 (6)	0·45 (7)	0·27 (5)	0·15 (3)
"Oxygen absorbed" at 27° C. in *4 hours*	5·28 (6)	2·01 (7)	1·42 (5)	0·60 (4)
Incubator Test (Scudder)	—	5+ (5)	4+ (4)	2+ (2)
Incubator Test (by smell)	—	6+ (6)	5+ (5)	2+ (2)
Oxygen in solution when analysed	—	0·75 (3)	0·68 (3)	—
Dissolved Oxygen taken up from water at 18° C. in 24 hours	—	—	0·21 (2)	—
Dissolved Oxygen taken up from water at 18° C. in 48 hours	—	—	—	—
Dissolved Oxygen taken up from water at 18° C. in 5 days	10·2 (4)	1·35 (5)	1·43 (3)	0·41 (3)
Chlorine	7·36 (5)	6·93 (7)	6·80 (7)	—
Solids in Suspension	4·0 (6)	6·7 (7)	4·3 (7)	—
Volatile matter in those Solids	3·2 (6)	4·6 (7)	2·8 (7)	—
Solids by Centrifuge (vols.)	24·9 (6)	100·9 (6)	61·0 (6)	—
Ratio of Solids in suspension to Centrifuge Solids	1 : 6·2 (6)	1 : 15·8 (6)	1 : 14·4 (6)	—
Calculated strength*	37·2 Taking Ammon. + organic N = 3·27 Nitric N = 0·38 Ox. abs., in 4 hrs. = 3·94.	—	—	—
Calculated oxidizability of whole effluent, including the suspended solids and giving credit for the nitrate present	—	6·5	—	—
Calculated oxidizability of effluent, excluding suspended solids and giving credit for nitrate	—	– 2·7	—	—
Calculated oxidizability of effluent, excluding solids and giving no credit for nitrate	—	3·3	—	—

Experiment A1. June 14th—November 6th, 1907.

Rate of Filtration—157 gallons per cube yard per day.

Since only two samples each of precipitation liquor and of filter effluents were examined during this experiment, no detailed deductions can be drawn from it, especially as the samples of liquor analysed were of very different strengths. The filter effluents, however, were during this period of the same character as during the period of Experiment A.

Experiment A1. 157 Gallons per cube yard. Parts per 100,000.

———	Precipitation liquor.	Unsettled filter effluent.	Settled filter effluent.	
			Original effluent.	Effluent after filtration through paper.
Ammoniacal Nitrogen	3·21 (2)	0·60 (2)	1·00 (1)	0·63 (2)
Albuminoid Nitrogen	0·41 (2)	0·21 (2)	0·26 (1)	0·08 (2)
Total Organic Nitrogen	0·86 (2)	0·38 (2)	—	0·26 (2)
Nitrous Nitrogen	—	0·03 (2)	0·0 (1)	0·0 (2)
Nitric Nitrogen	—	2·13 (2)	1·76 (2)	2·06 (2)
Total Nitrogen (by Kjeldahl)	4·06 (2)	3·14 (2)	—	2·95 (2)
"Oxygen absorbed" at 27° C. *at once*	3·33 (2)	0·51 (2)	—	0·21 (2)
"Oxygen absorbed" at 27° C. in *4 hours*	7·68 (2)	2·38 (1)	—	0·81 (1)
Incubator test (Scudder)	—	—	—	2 + (2)
Incubator test (by smell)	—	—	—	2 + (2)
Oxygen in solution when analysed	—	0·21 (2)	0·23 (2)	—
Dissolved Oxygen taken up from water at 18° C. in 24 hours	—	—	—	—
Dissolved Oxygen taken up from water at 18° C. in 48 hours	—	0·53 (2)	—	0·10 (2)
Dissolved Oxygen taken up from water at 18° C. in 5 days	13·8 (1)	1·62 (2)	—	0·35 (2)
Chlorine	10·05 (2)	8·93 (2)	8·83 (2)	—
Solids in suspension	8·6 (2)	4·3 (2)	3·1 (2)	—
Volatile matter in those Solids	7·2 (2)	3·8 (2)	2·8 (2)	—
Solids by Centrifuge (vols.)	36·5 (2)	90·1 (2)	56·8 (2)	—
Ratio of Solids in suspension to Centrifuge Solids	1 : 4·2 (2)	1 : 21·5 (2)	1 : 18·3 (2)	—

* Allowing for the abnormal ratio between the figures for "oxygen absorbed" at once and in 4 hours.

Experiment B. November 7th, 1907—June 4th, 1908, Rate of Filtration—183 gallons per cube yard per day.

Nine samples each of precipitation liquor and of the filter effluents were examined during this experiment. The strength of the liquor treated was greater than in Experiment A, and there were rather more suspended solids in the effluent as it issued from the filters. The figures of analysis show that the effluent, apart from its solids, though still of good quality, was not of quite such high class as that of Experiment A.

Experiment B. 183 gallons per cube yard. Parts per 100,000.

——	Precipitation liquor.	Unsettled filter effluent.	Settled filter effluent.	
			Original effluent.	Effluent after filtration through paper.
Ammoniacal Nitrogen	2·87 (9)	1·19 (9)	—	1·24 (9)
Albuminoid Nitrogen	0·45 (9)	0·30 (9)	—	0·13 (9)
Total Organic Nitrogen	0·99 (9)	0·71 (9)	—	0·32 (9)
Nitrous Nitrogen	0·01 (9)	0·03 (9)	—	0·02 (9)
Nitric Nitrogen	0·14 (9)	1·71 (9)	—	1·64 (9)
Total Nitrogen (by Kjeldahl)	4·02 (9)	3·55 (9)	—	3·25 (9)
"Oxygen absorbed" at 27° C. *at once*	2·71 (9)	0·61 (9)	—	0·26 (9)
"Oxygen absorbed" at 27° C. in *4 hours*	7·76 (9)	2·64 (9)	—	1·04 (9)
Incubator Test (Scudder)	—	7 + 2 − (9)	—	6 + 1 − (7)
Incubator test (by smell)	—	9 + (9)	—	7 + (7)
Oxygen in solution when analyzed	—	0·54 (9)	0·63 (9)	—
Dissolved Oxygen taken up from water in 24 hours, at 18° C.	—	—	—	—
Dissolved Oxygen taken up from water in 48 hours at 18° C.	—	1·26 (9)	—	0·29 (9)
Dissolved Oxygen taken up from water in 5 days at 18° C.	13·1 (4)	4·57 (9)	—	1·33 (9)
Chlorine	8·79 (9)	8·06 (9)	—	8·11 (9)
Solids in suspension	7·3 (9)	8·2 (9)	4·6 (9)	—
Volatile matter in those Solids	5·8 (9)	5·9 (8)	3·3 (9)	—
Solids by Centrifuge (vols.)	21·4 (9)	145·5 (9)	74·2 (9)	—
Ratio of Solids in suspension to Centrifuge Solids	1 : 2·9 (9)	1 : 17·6 (8)	1 : 16·2 (9)	
Calculated Strength*	54·8	—	—	—
	Taking Ammon. + organic N = 3·86 Nitric N = 0·14 Ox. abs., in 4 hrs. = 6·31			
Calculated oxidizability of whole effluent, including the suspended solids and giving credit for the nitrate present	—	15·2	—	—
Calculated oxidizability of effluent, excluding suspended solids and giving credit for nitrate	—	3·4	—	2·1
Calculated oxidizability of effluent, excluding solids and giving no credit for nitrate	—	8·6	—	7·0

**Cf.* Note ‡, p. 222.

Experiment C. June 5th—October 15th, 1908. Rate of Filtration—217 gallons per cube yard per day.

Eight samples each of precipitation liquor and of effluents were examined in this case, the liquor being stronger than it was during Experiment A, but not quite so strong as during Experiment B. The effluent issuing from the filters contained rather less suspended solids than the corresponding effluent of B, this being no doubt due to the fact that the spring out-flush of solids from the filter was over before this experiment began, though we made no actual observations on that point; the liquid portion of the effluent was also better oxidized.

Experiment C. 217 gallons per cube yard. Parts per 100,000.

——	Precipitation liquor.	Unsettled filter effluent.	Settled filter effluent.	
			Original effluent.	Effluent after filtration through paper.
Ammoniacal Nitrogen	3·18 (8)	1·03 (8)	—	1·05 (8)
Albuminoid Nitrogen	0·44 (8)	0·24 (8)	—	0·11 (8)
Total Organic Nitrogen	0·92 (8)	0·48 (8)	—	0·25 (6)
Nitrous Nitrogen	—	0·06 (8)	—	0·05 (8)
Nitric Nitrogen	—	1·78 (8)	—	1·83 (8)
Total Nitrogen (by Kjeldahl)	4·11 (8)	3·35 (7)	—	3·19 (8)
"Oxygen absorbed" at 27°C *at once*	3·16 (8)	0·59 (8)	—	0·26 (8)
"Oxygen absorbed" at 27° C. *in 4 hours*	7·40 (8)	2·29 (8)	—	1·01 (8)
Incubator Test (Scudder)	—	6+ (6)	—	7+ (7)
Incubator Test (by smell)	—	6+ (6)	—	7+ (7)
Oxygen in solution when analysed	—	0·25 (7)	0·31 (8)	—
Dissolved Oxygen taken up from water at 18°C. in 24 hours	—	—	—	—
Dissolved Oxygen taken up from water at 18°C. in 48 hours	—	1·27 (8)	—	0·17 (8)

Experiment C. 217 gallons per cube yard. Parts per 10,000.—continued.

——	Precipitation liquor.	Unsettled filter effluent.	Settled filter effluent. Original effluent.	Settled filter effluent. Effluent after filtration through paper.
Dissolved Oxygen taken up from water at 18°C. in 5 days	—	3·44 (7)	—	0·48 (7)
Chlorine	10·23 (8)	9·87 (8)	9·69 (8)	9·69 (8)
Solids in suspension	8·3 (8)	7·2 (8)	4·0 (8)	—
Volatile matter in those Solids	6·4 (8)	5·3 (8)	2·7 (7)	—
Solids by Centrifuge (vols.)	24·8 (8)	121·6 (8)	63·1 (8)	—
Ratio of Solids in suspension to Centrifuge Solids	1 : 3·0 (8)	1 : 17·0 (8)	1 : 16·0 (8)	—
Calculated Strength*	50·3 Taking Ammon. + organic N = 4·10 Ox. abs., in 4 hrs. = 5·30	—	—	—
Calculated oxidizability of whole effluent, including the suspended solids and giving credit for the nitrate present	—	12·1	—	—
Calculated oxidizability of effluent, excluding suspended solids and giving credit for nitrate	—	1·5	—	0·4
Calculated oxidizability of effluent, excluding solids and giving no credit for nitrate	—	6·8	—	5·9

* *Cf.* Note ‡ p. 222.

Experiment D. October 16th, 1908—January 21st, 1909.

Rate of Filtration—250 gallons per cube yard per day.

Seven samples each of precipitation liquor and of effluents were examined during this experiment, which —it will be noted—took place during the colder months of the year. The liquor treated was of about the same strength as in Experiment B, and slightly stronger than in Experiment C. The solids in the effluent as it came from the filter had now increased appreciably, and the liquid portion of the effluent was not quite so well oxidized as in Experiment C, though it was still good.

Experiment D. 250 gallons per cube yard. Parts per 100,000.

——	Precipitation liquor.	Unsettled filter effluent.	Settled filter effluent. Original effluent.	Settled filter effluent. Effluent after filtration through paper.
Ammoniacal Nitrogen	2·92 (7)	1·79 (7)	—	1·68 (7)
Albuminoid Nitrogen	0·47 (7)	0·36 (7)	—	0·15 (7)
Total Organic Nitrogen	0·99 (7)	0·81 (5)	—	0·49 (7)
Nitrous Nitrogen	0·0 (2)	0·05 (7)	—	0·04 (7)
Nitric Nitrogen	0·42 (2)	1·14 (7)	—	1·22 (7)
Total Nitrogen (by Kjeldahl)	4·10 (7)	3·68 (7)	—	3·43 (7)
"Oxygen absorbed" at 27° C. *at once*	2·65 (7)	0·86 (7)	—	0·37 (7)
"Oxygen absorbed" at 27° C. *in 4 hours*	7·74 (7)	3·33 (7)	—	1·40 (7)
Incubator test (Scudder)	—	5+ 2− (7)	—	6+ (6)
Incubator test (by smell)	—	5+ 2− (7)	—	6+ (6)
Oxygen in solution when analysed	—	0·30 (7)	0·39 (7)	—
Dissolved Oxygen taken up from water at 18° C. in 24 hours	—	—	—	—
Dissolved Oxygen taken up from water at 18° C. in 48 hours	—	2·20 (7)	—	0·30 (7)
Dissolved Oxygen taken up from water at 18° C. in 5 days	—	5·27 (7)	—	0·78 (7)
Chlorine	9·72 (7)	9·20 (7)	9·22 (7)	—
Solids in suspension	10·0 (7)	9·2 (7)	5·3 (7)	—
Volatile matter in those Solids	7·7 (7)	6·9 (7)	4·1 (7)	—
Solids by Centrifuge (vols.)	24·0 (7)	142·1 (7)	75·3 (7)	—
Ratio of Solids in suspension to Centrifuge Solids	1 : 2·4 (7)	1 : 15·4 (7)	1 : 14·1 (7)	—
Calculated strength*	55·8 Taking Ammon. + org. N = 3·91 Ox. abs. in 4 hours = 6·36	—	—	—
Calculated oxidizability of whole effluent, including the suspended Solids and giving credit for the nitrate present	—	22·1	—	—
Calculated oxidizability of effluent, excluding suspended Solids and giving credit for nitrate	—	8·3	—	6·1
Calculated oxidizability of effluent, excluding Solids and giving no credit for nitrate	—	11·7	—	9·8

* *Cf.* Note ‡, p. 222. The Nitric Nitrogen has not been taken into account here.

Summary of Results.

All the foregoing filtration results (except those of Experiment A_1, where the data are few) are summarised *approximately* in the appended Table, which is on exactly the same lines as Table II. in the Memorandum on Work Done by Sewage Filters. (This appendix, p. 30.)

(c)	B. Calculated strength of liquor treated.	C. Filter Effluent. Figures of Analysis. Ammoniacal+Organic Nitrogen.	C. Volatile Solids.	C. "Oxygen absorbed" from Permanganate in 4 hours.	C. Nitric Nitrogen.	D. Strength or Oxidizability of Filter Effluent. (a) Whole Effluent, including Suspended Solids.	D. (b) Effluent without Suspended Solids.	D. Effluent without Suspended Solids and Nitrate.	E. Oxygen used up in producing this Effluent (B–D (a)).	F. Gallons of liquor treated per cube yard of Filter per day.	F_1. Units of Oxidizable Matter treated per cube yard of Filter.	G. Relative purification effected by 1 cube yard of Filter.	G_1. Percentage Purification. (a) On Atmospheric Oxygen taken up in the process.	G_1. (b) On Atmospheric Oxygen taken up, leaving out of account the Suspended Solids of the Effluent.	G_1. (c) On Atmospheric Oxygen taken up, leaving out of account the Suspended Solids and Nitrate of the Effluent.	G_1. (d) On "Oxygen absorbed" from Permanganate in 4 hours (including the Suspended Solids of the Effluent).
Septic Tank Liquor and Settled Filter Effluent. (Hourly samples.) May 16th, 17th, and 18th, 1904 - - - -	68·7	1·01	1·6	1·68	2·15	4·3	0·7	4·5	64·4	150	10,305	9,660	94	99	93	84
7 chance samples septic liquor and 8 chance samples settled effluent, Nov., 1902—Nov., 1905	62·1															
Precipitation Liquor. (Hourly samples.) May 16th, 17th and 18th, 1904 - - - -	74·0															
Precipitation Liquor and Unsettled Filter Effluent.																
Experiment A—(Aug. 3rd, 1906—June 13th, 1907)	37·2	0·74	4·6	2·01	2·02	6·5	—2·7	3·3	30·7	133	4,948	4,083	83	107	91	62
Experiment B—(Nov. 7th, 1907—Jan. 4th, 1908) -	54·8	1·90	5·9	2·64	1·71	15·2	3·4	8·6	39·6	183	10,028	7,039	72	94	84	66
Experiment C—(June 5th, 1908—Oct. 15th, 1908)-	50·3	1·51	5·3	2·29	1·78	12·1	1·5	6·8	38·2	217	10,915	8,289	76	97	86	69
Experiment D—(Oct. 16th, 1908—Jan. 21st, 1909) -	55·8	2·60	6·9	3·33	1·14	22·1	8·3	11·7	33·7	250	13,950	8,425	60	85	80	57

It is not possible to make an exact comparison between the work actually done by the filters when treating septic liquor and precipitation liquor, respectively, because—(1) Only the hourly samples of the settled filter effluent (and not of the unsettled) from the septic tank liquor were examined ; (2) the chance samples of filter effluent, (settled and unsettled) from the septic tank liquor were only partially analysed.

Still, it will be possible to make a fairly accurate comparison.

As seen in the above Table, both the hourly and chance samples of septic tank liquor (1904 and 1902–5) and the hourly samples of precipitation liquor (1904) were stronger than the chance samples of precipitation liquor of Experiments B, C and D, and very much stronger than the precipitation liquor of Experiment A. At the time when the hourly samples of septic liquor were drawn, the filters were treating 150 gallons per cube yard. These 150 gallons contained aggregate oxidizable matter equivalent to 10,305 units, as against 10,028 units in the precipitation liquor of Experiment B (at 183 gallons per cube yard), and 10,915 units in the liquor of Experiment C (at 217 gallons per cube yard). So far, therefore, as hourly samples, drawn over three consecutive days, can be compared with chance samples drawn over periods of six and four and a half months, the filters were receiving during these three periods much the same quantities of oxidizable matter, and the filter effluents ought therefore to be fairly comparable with one another.

It has been shown in the Accrington experiments, where septic liquor alone was treated (p. 72), that within ordinary limits of strength of liquor treated, the purification effected per cube yard of filtering material was much the same, whether the filter was treating one volume of strong liquor or two volumes of the same liquor, diluted with water to half the original strength, at rates inversely proportional to the strengths.

Taking a few of the chief figures of analysis of the effluents in question, we have :—

Parts per 100,000.

——	Settled filter effluent from septic tank liquor. (Hourly samples.)	Unsettled filter effluent from :— Precipitation liquor. Experiment B.	Unsettled filter effluent from :— Precipitation liquor. Experiment C.
Ammoniacal nitrogen - - - - - - - - -	0·51	1·19	1·03
Total Organic Nitrogen - - - - - - - -	0·50	0·71	0·48
Oxidized Nitrogen - - - - - - - -	2·17	1·74	1·84
"Oxygen absorbed" in 4 hours - - - - - -	1·68	2·64	2·29
Solids in suspension - - - - - - - -	2·2	8·2	7·2
Calculated oxidizability :—			
(a) of whole effluent - - - - -	4·3	15·2	12·1
(b) of effluent without solids - - - - -	0·7	3·4	1·5
(c) of effluent without solids and nitrate - -	4·5	8·6	6·8

The comparatively high figures for organic nitrogen and for "oxygen absorbed" in four hours are largely due to the suspended solids in the effluents, as is seen by referring to the analysis, in Experiments B and C, of the settled filter effluents after paper filtration. Still, the ratio of ammoniacal to oxidized nitrogen is less in the filter effluent from the septic liquor, which is therefore in this respect the better, thus :—

Filter effluent :—	From septic liquor.	From precipitation liquor.	
		Experiment B.	Experiment C.
Ammoniacal Nitrogen - - - - - - - -	0·51	1·19	1·03
Oxidized Nitrogen - - - - - - - -	2·17	1·74	1·84

If we take the calculated oxidizability of the respective effluents, apart from suspended solids, we have :—

Effluent from septic liquor.	Effluent from precipitation liquor.	
	Experiment B.	Experiment C.
0·7	2·1	0·4

Here there is no difference between the first and third, and not much between these and the second.

The units of purification are :—

	Effluent from Septic liquor.	Effluent from precipitation liquor.	
		B.	C.
Calculated units of purification (including the suspended solids in the settled effluent) - - -	9,660	7,039	8,289
Calculated units of purification, assuming five parts of suspended solids as a fair average for the filter effluent * - - - - - - -	8,640		
Calculated units of purification, excluding the suspended solids - - - - - - -	10,200	9,406	10,590

Practically, therefore, and allowing for the fact that the above comparison cannot be a strictly exact one, it may be said that there was little or no difference in the aggregate work effected by the filters at Rochdale during the periods in question, whether they were treating septic or precipitation liquor. If anything, perhaps the balance is in favour of the septic liquor. The temperature conditions were probably fairly comparable during these three experiments.

As has been already said in the memorandum on the work done by filters (*loc. cit.*), the nitrogen stage of the oxidization of sewage liquors probably requires, unit for unit, a larger amount of energy than the carbon stage. If the *relative* proportions of nitrogeneous and carbonaceous matter, therefore, had differed materially in the septic and precipitation liquors, this might conceivably have influenced the results of the filtration. But apparently there was no very great difference between the liquors in this respect, if we may judge by the following ratios :—

Ratio of :—	Ammon. + Organic Nitrogen.	"Oxygen absorbed" in 4 hours (corrected).†
Septic Liquor, Hourly Samples - - - - -	1	1·42
Septic Liquor, Chance Samples - - - - -	1	1·48
Precipitation Liquor, Hourly Samples - - -	1	1·67
Precipitation Liquor, Chance Samples, Experiment A	1	1·20
Precipitation Liquor, Chance Samples, Experiment B	1	1·63
Precipitation Liquor, Chance Samples, Experiment C	1	1·29
Precipitation Liquor, Chance Samples, Experiment D	1	1·63

Experiments A and D.

Only a few words need be added here with respect to the precipitation liquor experiments A and D. In A (at all events, when the samples analysed were being drawn) the filters were treating only 133 gallons per cube yard per day of a much weaker precipitation liquor than usual, and were producing a high class effluent which contained nearly all its nitrogen in the oxidized state and took up very little dissolved oxygen from water in five days. The filters were at this time working well within their capacity.

In experiment D, the filters were treating 250 gallons per cube yard of a liquor of much the same strength as in experiments B and C, and this in the colder months of the year. Notwithstanding this large dose, the effluent—apart from its suspended solids—was of fair quality, containing about one-third of its nitrogen in the oxidized state and taking up only 0·78 part of dissolved oxygen in five days. At the same time, the aggregate purification effected during experiment D was only about the same as during experiment C (8,425 units, as against 8,289, including the suspended solids of the effluent), while the percentage purification had fallen materially (*cf.* Table on p. 227). It would seem, therefore, that 250 gallons per cube yard is somewhere near the limit of volume at which the Rochdale precipitation liquor can be filtered through coarse material, so as to produce a reasonably good effluent.

During the whole course of the experiments A to D, there was no appreciable ponding on the surface of the filters, excepting at parts which had been much trodden.

By referring to the section upon Rochdale in Appendix III, p. 467, it will be seen that Mr. Platt had found by experience that a rate of 167 gallons per cube yard per day was too much, when the filters were treating septic tank liquor, giving rise to ponding on the surface of the filter and deterioration in the quality of the effluent, and he reverted to the 133 gallon rate. If, however, we take

* This assumption is a deduction from the results of the analysis of the effluents, and is probably near the truth.
† *Cf.* Notes † and ‡, p. 222.

150 gallons as the rate for septic tank liquor, beyond which it would not be prudent to go, even this compares unfavourably, as regards volume, with the 217 gallon rate for precipitation liquor of Experiment C.

The general conclusion to be drawn, therefore, both from the experience of the Rochdale Authorities and from the Commission's experiments, is that owing to the reduction in strength of sewage brought about by the addition of precipitants, at least one third more precipitation liquor than septic liquor can be filtered per cube yard at Rochdale, but that the resulting filter effluent from the precipitation liquor—while very good—is not quite so highly nitrated as that from the septic liquor. Given similar conditions of *internal* surface area in the filter, the time of "percolating contact" would, with the larger flow, be shorter in the case of the precipitation liquor.* It has also to be borne in mind that against the advantage of the larger volume dealt with, in the case of the precipitation liquor, would have to be placed the extra labour and cost entailed by the increased quantity—at least one-third more—of sludge produced.

The conclusions arrived at by the Commission and given in the Fifth Report, viz. :—

(1) That, within ordinary limits, the rate at which a sewage liquor can be filtered is in approximate inverse ratio to its strength ; and (2) that the more efficient the preliminary or tank treatment, the smaller is the cubic area of filter required for the second or oxidizing process—are thus fully confirmed by these experiments at Rochdale. The latter also show that, for practical purposes, and so far as the resulting effluent is concerned, it matters little whether the sewage is treated by septic tank and a larger area of filter, or by chemical precipitation and subsidence and a smaller area. The choice of the preliminary process would thus depend upon other considerations, such as facility for disposal of sludge, and whether it was necessary to keep down smell as far as possible in the distribution of the sewage liquor on to the filter.

In conclusion, we desire to express our cordial thanks to the Sewage Committee of the Rochdale Borough Council and to Mr. S. S. Platt, the Borough Surveyor, for placing at our disposal, for the Commission, the experimental percolating filters at Roch Mills. To Mr. Platt we are further indebted for much invaluable help during the course of the experiments. Our thanks are also due to Mr. H. Ledson, the manager of the Sewage Works at Roch Mills, who devoted much time and trouble to the working of the filters and to the collection of samples.

GEORGE McGOWAN.
COLIN C. FRYE.

August, 1909.

REPORT UPON EXPERIMENTS CARRIED OUT AT ILFORD.

By Dr. G. McGowan.

The Commission's experiments at Ilford were begun in the early part of 1901 and were continued, with periods of intermission, until the autumn of 1908. The main objects of the experiments were :—

1. To test the relative efficiency of deep and shallow filters, filled with rather coarse material.

2. To determine the extent to which the sewage underwent digestion in a septic tank.

The results as regards septic tank digestion, in the very carefully controlled experiment which lasted from November, 1904, to August, 1906, have been referred to in the Fifth Report of the Commission, p. 22, and have been given in more detail in this Appendix, p. 249.

It is therefore unnecessary to say more here than that the digestion at Ilford, where the sewage is virtually a domestic one of about average strength, amounted to about 30 per cent. ; or, applying an approximate correction for the colloids in both the sewage and the septic liquor, to about 23 per cent.

The earlier experiment on septic tank digestion was not made with the same degree of accuracy, much fewer samples of sewage and septic tank liquor having been examined during its progress, so its results need hardly be given.

The points which were under investigation at Ilford have also been the subject of study at a number of other places by different observers, as well as by ourselves on behalf of the Commission. While it will not therefore be necessary to enter into great detail with regard to them in this Report, a short record of the progress of the experiments may be of some interest.

By the kind permission of the Ilford Urban District Council, and for the most part at their own cost, the installation was constructed at the main outfall works by Mr. H. Shaw, A.M.I.C.E., Engineer and Surveyor to the Council, assisted by Mr. Percy Taylor, A.M.I.C.E., (now Surveyor to the Urban District Council at Hampton Wick), and Mr H. Chittock, Sewage Works Manager.

It consisted of a concreted septic tank of 18,000 gallons capacity, 30 feet long, 20 feet wide, and 5 feet deep, which was fed from the main sewage channel at the entrance to the works, after the sewage had passed through the grit tanks. The flow was regulated by means of a valve placed in the entrance channel to the septic tank ; this regulation was not so good as in the later experiments, when a gauge was employed.

The sewage entered the tank over a sill which reached across the entire width. Having passed through the tank, the septic liquor left it over another sill, also stretching the whole way across, and it then flowed in an underground pipe, laid about a foot below the surface, to the small experimental filters, which were at a distance of about 700 feet from the tank, the fall between the outlet end of the tank and the feed channels at the filters being 1 foot 6 inches. This was the most suitable arrangement which could be made, having regard to the configuration of the main works and to the ground available.

The flow through the tank during much the greater part of the time that the experiments lasted was at the rate of once in 24 hours. In order to ensure its continuing fairly uniform, it was necessary that the small space at the foot of the penstock, which regulated the flow in the feed-channel to the tank, should be kept open, by being occasionally cleared with a piece of thick wire. Otherwise, this space was apt to become more or less blocked by pieces of paper, etc. The flow was gauged from time to time, and was on the whole found to keep fairly satisfactory.

The filters had the following dimensions† :—

	Length.	Breadth.	Depth.	Cubic capacity.
	Ft. in.	Ft. in.	Ft. in.	Cube yards.
Deep filter - - - - -	12 0	9 0	6 0	24
Shallow filter - - - -	12 0	9 0	3 0	12

* *Cf.* The Dorking Experiments. (This Appendix, p. 199 *et seq.*)

† A measurement made in June, 1906, after the filters had been in use for a long time, gave :—

	Length.	Breadth.	Depth.	Cubic capacity.
	Ft. in.	Ft. in.	Ft. in.	Cube yards.
Deep filter - - - - -	12 0	9 3	6 0	24·7
Shallow filter - - - -	12 1	9 2	3 0	12·3

Owing to the levels, the filters had to be sunk in the ground, and in the earlier experiments they were boarded up on the three open sides of each filter, there being 8 boards on each side of the deep filter and 6 boards on each side of the shallow. The material was good washed coke of 1½ inches to 3 inches diameter; this was of very even size. Each filter was drained by a main drain pipe running along one side, 1 foot in diameter and with open joints; connected with this there were four branch perforated drain pipes, 6 inches in diameter, also with open joints, which ran across the filter.

The effluents could be sampled separately at their respective outlet pipes, below these being two manholes in which the effluent solids collected, to be cleaned out as required. The mixed effluents then flowed into a small stream, close by, which eventually joined the Thames at Barking.

There were six Stoddart trays on each of the filters, the actual surface covered by the six trays being about 72 square feet. Of the 108 square feet of each filter, therefore, 36 square feet or one third of the whole were uncovered. The trays were thinner than those now used by Mr. Stoddart, and were therefore more apt to "buckle" with changes of temperature. They were throughout kept as carefully adjusted for level as possible. The trays were fed in couples from two shallow channels which ran the whole length of the filters, though at different levels. The regulation of the flows to the two channels was effected at a small concreted manhole close to the filters, 3 feet long and 2 feet broad; this had two outlets, which were controlled by two wooden penstocks. It was at the entrance to this small manhole that the samples of septic liquor were drawn, excepting during the second digestion experiment in 1904–6, when these were taken at the outlet to the septic tank. A few samples, at the very beginning of the experiments in 1901, were drawn from different parts of the tank itself. The experimental septic tank was filled with crude sewage on March 7th, 1901, and allowed to stagnate. On April 11th the filters began to be matured with gradually increasing quantities of liquor, and on April 15th the trays were fixed in position.

Experiment A. April 11th—June 3rd, 1901.

During this period the filters were maturing, tank liquor being run on to them from April 18th for two or three separate hours each day (total, for both filters = 1,500 to 2,250 gallons per day).

The following are the figures of analysis of a sample of tank liquor drawn from the tank itself, May 10th, 1901.

Parts per 100,000.

Ammoniacal Nitrogen - - - - -	5·36
Albuminoid Nitrogen - - - - -	0·77
Total Organic Nitrogen - - - -	1·42
Total Nitrogen (by Kjeldahl) - -	6·78
*"Oxygen absorbed" at 27° C. *at once* -	1·78
"Oxygen absorbed" at 27° C. *in 4 hours*	5·19
†Chlorine - - - - - - -	12·60
Solids by centrifuge (vols.) - - -	45·6

Several samples of effluent from both filters were examined during this preliminary period. Towards the end of it the formation of nitrate had begun, though the nitrate only showed to any extent in the drainings from the filters.

It should be mentioned that during the whole of the experiments the channels at the filters and the filter trays were swept from time to time, as required, usually about once a week, the sediment being returned to the septic tank, until the second digestion experiment was begun, when it was put upon land; while at much longer intervals the manholes receiving the filter effluents were emptied of their solids, which were usually put on the land.

Experiment B. June 4th—June 13th, 1901.

	Tank.	Deep Filter.	Shallow Filter.
Flow through (in gallons) -	18,000	6,000	3,000
Equivalent to gallons per cube yard per day - -	—	250	250

Two samples of tank liquor drawn during this period gave:—

	(a)	(b)
Total Nitrogen - - - -	7·09	7·18
"Oxygen absorbed" *in 4 hours*	7·64	6·86

Two samples of effluent from each filter showed very little oxidized nitrogen, thus:—

Effluent from	Deep Filter.		Shallow Filter.	
Nitrous Nitrogen - - -	0·06	0·23	0·09	0·06
Nitric Nitrogen - - -	0·13	0·19	0·17	0·08

Experiment C. June 14th—July 22nd, 1901.

	Tank.	Deep Filter.	Shallow Filter.
Flow through (in gallons) -	18,000	4,000	2,000
Equivalent to gallons per cube yard per day - -	—	167	167

On June 26th, scum began to form on the liquid in the tank, and on July 11th it had a thickness of 2 to 3 inches, the sludge being at that date about 4 inches deep. During this period four sets of samples were analysed.‡

The samples of tank liquor gave the average figures:—

Total Nitrogen - - - - -	7·33 (4)
"Oxygen absorbed" *in 4 hours* - -	7·33 (3)

All the samples of filter effluent were turbid and greenish-brown in colour, with varying quantities of sediment. They showed however a distinct improvement on the preceding set, and gave the following average figures:—

Effluent from	Deep Filter.	Shallow Filter.
Nitrous Nitrogen - - -	0·16 (4)	0·11 (4)
Nitric Nitrogen - - -	0·68 (4)	0·57 (4)
Incubation (by smell) - -	1+, 2−, (3)	1(?), 3−, (4)

It is to be noted that neither of the last pair of effluents (drawn July 12th) showed more than a trace of oxidized nitrogen.

July 23rd, 27th, 1901.—Some new trays were fitted on to the filters.

Experiment D. July 28th—November 28th, 1901.

	Tank.	Deep Filter.	Shallow Filter.
Flow through - - -	18,000	12,000 §	6,000 §
Equivalent to gallons per cube yard per day - -	—	500	500

During this experiment fifteen samples each of septic tank liquor and of deep and shallow filter effluents were examined. ‖

* "Strong," *i.e.* $\frac{N}{8}$ permanganate (3·94 grms. $KMnO_4$ per litre), was always used for this test.

† The chlorine in the Ilford sewage has no significance as a guide to strength, because of the large quantities of sodium chloride solution that get into the sewers from the Ilford photographic works.

‡ The first two of these were drawn from various parts of the tank, at a depth of 2 feet, and the other two at the dividing manhole near the filters. The first couple contained much more suspended solids than a true sample would have done.

§ Excepting from September 4th–15th inclusive, when the liquor was run through the tank only.

‖ Two further samples of tank liquor, Nos. 83 and 86, were also analysed, but their figures are not included here, because the corresponding filter effluents were not examined. They were rather stronger than the average, especially No 86.

The tank liquor gave the following average figures :—

Parts per 100,000.			*Average.*	
Ammoniacal Nitrogen	5·31 to 6·90	- -	6·11	(15)
Albuminoid Nitrogen	0·40 to 0·77	- -	0·54	(15)
Total Organic Nitrogen	0·78 to 1·93	- -	1·27	(15)
Total Nitrogen (by Kjeldahl)	6·31 to 8·61	- -	7·39	(15)
"Oxygen absorbed" at 27° C. *at once*	2·16 to 3·85	- -	3·25	(15)
"Oxygen absorbed" at 27° C. *in 4 hours*	6·00 to 8·10	- -	6·93	(15)
Chlorine	16·9 to 24·8	- -	20·3	(14)
Solids by centrifuge (vols.)	28·5 to 106·0	- -	53·7	(15)
Equivalent to solids in suspension *	—	- -	7 to 8 approx.	
Calculated "Strength" †	—	- -	64·4	

It will be noted that the samples of tank liquor were of very even composition throughout this experiment; further, that they were of much the same strength as the average fortnightly samples taken during the two years 1904–6.

The corresponding fifteen deep and shallow filter effluents gave the following figures ‡ :—

Parts per 100,000.	Deep Filter Effluent. *Average.*	Shallow Filter Effluent. *Average.*
Ammoniacal Nitrogen	0·44 to 6·59—5·30 (13)	3·98 to 6·69—5·05 (13)
Albuminoid Nitrogen	0·36 to 0·57—0·47 (10)	0·34 to 0·56—0·45 (11)
Total Organic Nitrogen	0·60 to 1·22—0·88 (12)	0·45 to 1·15—0·80 (12)
Nitrous Nitrogen	0·0 to 0·34—0·12 (14)	0·0 to 0·28—0·13 (13)
Nitric Nitrogen	0·0 to 0·42—0·19 (13)	0·0 to 0·63—0·15 (13)
Total Nitrogen (by Kjeldahl)	5·21 to 7·42—6·48 (13)	4·97 to 7·28—6·07 (13)
"Oxygen absorbed" at 27° C. *at once*	0·93 to 1·72—1·35 (15)	1·03 to 1·84—1·33 (15)
"Oxygen absorbed" at 27° C. *in 4 hours*	3·01 to 5·83—4·39 (12)	2·99 to 5·52—4·61 (13)
"Oxygen absorbed" after incubation, *in 4 hours*	3·41 to 9·03—6·20 (14)	2·88 to 8·49—5·74 (14)
Incubator test (by smell)	15 – (15)	15 – (15)
Chlorine	16·8 to 24·4—20·0 (13)	16·6 to 24·8—20·0 (12)
Solids by centrifuge (vols.)	20·9 to 120·0—70·3 (15)	19·0 to 127·0—60·7 (14)

The above thirty samples of deep and shallow filter effluent were more or less turbid with grey, green, or brown sediment and growths, but the best of them filtered through paper to clear and almost colourless liquids. On the day of analysis 11 out of each 15 had either a clean earthy or a seaweed smell, the remainder having a slight sewage odour. Not one sample, however, was able to withstand incubation. The result, therefore, of treating this medium-strength septic liquor, at the very high rate of 500 gallons per cube yard of coarse filtering material per 24 hours, was that the oxidation was almost confined to the carbonaceous matter present, the nitrogenous matter of the liquor being only slightly affected. There was practically nothing to choose, as regards quality, between the two sets of effluents.

On November 11th, 1901, two samples of gas were aspirated from the interior of each of the filters, at points where it might have been expected that any de-aeration would show itself. This was done by hammering into the filter a narrow piece of iron gas barrel (⅜″ internal diameter), temporarily plugged with a cork, which was knocked out by the aid of a long thin iron rod after the tube had reached the point desired. A suitable aspirator was then attached to the iron barrel by means of rubber and glass tubing, etc., and before actually collecting any gas, some 800 to 900 c.c. were first drawn off, so as to displace the air originally in the iron tube. The gases were subsequently analysed, with the following results :—

	From Deep Filter.		From Shallow Filter.	
	No. 1.	No. 2.	No. 3.	No. 4.
Depth at which sample was drawn	4 feet.	3 feet.	2 feet.	1·5 feet.
Per cent. found, by volume.				
Carbon Dioxide	0·36	0·36	0·44	Not analysed.
Oxygen	20·67	20·27	20·85	
Nitrogen	78·97	79·37	78·71	

These figures all represent practically pure air, and they are sufficient to show that at this time the filters were fully aerated throughout. The poor quality of the effluents was therefore not due to any lack of oxygen in the interior of the filters.

From time to time, during the progress of the experiments at Ilford, the depth of scum and of sludge in the tank was measured. The measurement of the sludge was made by means of a wide and *thick-walled* glass dipping tube, 8 feet long and 1⅝ inches internal diameter, protected at the ends by brass verrels, which projected slightly. The tube could be closed at will by a stopper which consisted of half a small rubber ball, of slightly greater diameter than the tube itself, and through the *centre* of which a stout endless cord was passed; immediately below the flat, *i.e.*, the lower side of the half ball, the cord was knotted. The upper vessel had soldered on to it a small brass hook, which allowed of the cord being securely fastened, *i.e.*, of the rubber stopper being fixed quite tightly after a dip had been made, and before the tube was drawn up for measurement of the sludge. The scum was measured by a foot-rule.

As a rule, six measurements were made at a time of the scum and sludge at parts in the tank which were selected as giving a fair average of the whole. It will not, however, usually be necessary to give more than the *average* figures for any one set of readings.

* Inferred from the ratio of solids in suspension to centrifuge solids in the fortnightly average samples of tank liquor drawn during the later sludge digestion experiment (1904–6).

† Making allowance for the abnormal ratio of "oxygen absorbed" at once to "oxygen absorbed" in 4 hours.

‡ Two further samples of each filter effluent were drawn fully half-way through the experiment), viz., Nos. 84 and 87 from the deep filter, and Nos. 85 and 88 from the shallow filter. They were, however, smelling strongly when they reached the laboratory and were not analysed.

	Scum.	Sludge.	Gallons of sewage which had passed through the tank.
	inches.	inches.	
September 22nd, 1901. Inlet end - - -	20	2 to 2½	—
" " " Outlet end - - -	5	2½ to 3*	2,299,500
October 21st, 1901. Inlet end - - - -	17	2½ to 3	—
" " " Outlet end - - -	6	5 to 6	2,821,500
November 27th, 1901. Inlet end - - -	24†	about 2	—
" " " Outlet end - - -	15	4 to 5	3,487,500

Experiment E. November 28th, 1901—April 3rd, 1902.

	Tank.	Deep Filter.	Shallow Filter.
Flow through (in gallons) - - - - - -	18,000	6,000	3,000
Equivalent to gallons per cube yard per day -	—	250	250

Experiment D had shown that the dose of 500 gallons per cube yard per day was too great for the filters, so on November 28th, 1901, the flow on to the filters was reduced to half of this, the tank still receiving 18,000 gallons a day.

During Experiment E, seven sets of septic tank liquor and of corresponding effluents were drawn.‡ The samples of septic liquor gave the following *average* figures, among others :—

Parts per 100,000.		*Average.*
Total Nitrogen - - - - - - - - - -	6·51 to 9·13 - -	7·65 (6)
"Oxygen absorbed" at 27° C. in *4 hours* - - - - -	6·13 to 8·95 - -	7·48 (5)
Solids in suspension - - - - - - - - -	8·2 to 10·0 - -	8·8 (3)

The liquor was thus of much the same strength as during Experiment D, though it no doubt contained rather more suspended solids, from the tank having been running for a longer time.

All the fourteen effluents of this experiment were more or less turbid and brownish liquids, containing some sediment and a good deal of green growth. Only one, or perhaps two, of the deep filter effluents had a clean smell on the day of analysis, and the same applied to those from the shallow filter. The first four pairs only were tested for oxidized nitrogen, the average figures being :—

	Deep Filter Effluent.	Shallow Filter Effluent.
Nitrous nitrogen - -	0·17	0·13
Nitric nitrogen - -	0·18	0·23

It may safely be inferred that all the samples would have putresced on incubation (only two of each were actually tested for this).

It is noteworthy that the effluents of Experiment E (at 250 gallons per cube yard) were not quite so good as those of Experiment D (at 500 gallons). The main reason for this was, no doubt, the lower temperature prevailing during Experiment E. It was also noted, on March 22nd, that there was ponding of the coke on several places on the deep filter.

On December 17th the distribution on to the deep filter was noted as being very fair.

On December 19th, 1901, the flow through the septic tank was regauged.

On December 20th the grit channel was cleaned out and the deposit put into the septic tank.

The following measurements of scum and sludge were made :—

	Scum.	Sludge.	Gallons of sewage which had passed through the tank.
	Inches.	Inches.	
January 3rd, 1902 :—Inlet end - - - -	20	3·5 to 6·5	4,153,500
" " Middle - - - - -	18	3·5 to 4	
" " Outlet end - - - -	15	6·5 to 9	
March 21st, 1902 :—Inlet end - - -	36	9	5,539,500
" " Middle - - - - -	36	5·5	
" " Outlet end - - - -	18	8	

On April 3rd, 1902, the flow through the septic tank was regauged, and on April 4th the flow was reduced both through the tank and the filters.

Experiment F. April 4th—June 11th, 1902.

	Tank.	Deep Filter.	Shallow Filter.
Flow through - - - - - - - - -	4,500	3,000	1,500
Equivalent to gallons per cube yard per day -	—	125	125

* On this date the middle of the tank gave a reading of 3 inches to 4 inches.

† One measurement.

‡ It is not quite certain that the first set, drawn on November 28th, may not rightly have belonged to Experiment D. It is, however, included in E.

Only one set of samples was drawn during this experiment, on May 26th, 1902. The tank liquor was of about the usual strength. The two samples of effluent were free from odour when drawn, but they had a smell the next day and were not analysed; on May 31st they smelt badly. They were thus of poor quality.

On May 26th the distribution was noted as being fairly good on both filters.

	Scum.	Sludge.	Gallons of sewage which had passed through the tank.
	Inches.	Inches.	
May 26th, 1902 :—Inlet end	31	6 to 7	6,039,000
" " Middle	31	2 to 4·5	
" " Outlet end	27	7	

On this occasion the scum was much more liquid than at the previous visit, the reduced flow and increased temperature having no doubt assisted digestion to some extent.

Analysis of Scum and Sludge.

The following estimations were made on samples of scum and sludge drawn from the tank on June 30th, 1902. For the previous three months the tank had been running at the slow rate of 4,500 gallons per day, but before that the rate had for a long time been 18,000 gallons.

The figures given are reckoned on the *dry* scum and sludge (*i.e.*, as dried in the hot-air bath).

	No. 1. Scum.	No. 2. Scum.	No. 3. Sludge.
	From top of scum, after rejecting about ¼ inch of dry humus matter, scratched up by the fowls.	From bottom of scum.	From a mixture of the six sub-samples obtained by the different dips.
	Per cent.	Per cent.	Per cent.
Volatile matter	49·9	53·6	52·0
Non-volatile matter	50·1	46·4	48·0
	100·0	100·0	100·0
"Cellulose"	10·8	—	—
Grit	28·2	—	—
Nitrogen (by Kjeldahl)	3·25	3·49	3·15

The above analyses show that, as regards volatile and non-volatile matter, and also as regards percentage of nitrogen, the scum and sludge did not at the time differ materially from one another.

Experiment G. June 13th, 1902—June 24th, 1903.

	Tank.
Flow through	4,500 gallons.

During this period the filters were merely kept moistened by running on tank liquor for two separate quarters of an hour each day. Six samples of tank liquor were drawn, viz., on June 30th, July 28th, and September 12th, 1902, and February 9th, April 30th, and June 18th, 1903, and these gave the following average figures on analysis :—

Parts per 100,000.		*Average.*
Total Nitrogen	3·84 to 7·78	6·59 (6)
"Oxygen absorbed" in 4 hours at 27° C.	2·54 to 7·97	6·19 (6)
Solids in suspension	3·8 to 6·4	5·2 (5)

The last sample, drawn on June 18th, 1903, was very dilute from recent heavy rains, but otherwise they were of very even composition and of about the same strength as usual.

The only samples of effluent, or, rather, of *drainings*, examined during this time were drawn on June 30th, 1902. They gave the figures :—

Drainings from :—	Deep Filter.	Shallow Filter.
	No. 140.	No. 141.
Nitrous Nitrogen	0·75	0·35
Nitric Nitrogen	3·98	2·78
"Oxygen absorbed" in 4 hours	4·01	4·01
Incubation (by smell)	+	+

These samples were brownish-grey and rather turbid, with moderate amounts of sediment, and they had a fishy smell when drawn. Although well nitrated, the large amount of nitrite present showed that they were not, even now, effluents of high class. It should, however, be borne in mind that the flow through the tank was very slow during this period (a flow of 4,500 gallons through a tank of 18,000 gallons capacity, but half full of scum and sludge); the tank liquor probably therefore contained a larger quantity than usual of sulphuretted hydrogen, which would tend to make it more difficult to purify.

On July 28th it was noted that the coke on the filters was much cleaner than a month before.

The following measurements of scum and sludge in the tank were made during this period :—

	Scum.	Sludge.		Gallons of sewage which had passed through the tank.
	Inches.	Inches.		
July 1st, 1902 :—Inlet end	27	11·25	5·5	6,201,000
Middle	26	4·5		
Outlet end	25	7·5		
July 28th, 1902 :—Inlet end	16	9	5·5	6,322,500
Middle	30	4·25	3·75	
Outlet end	18	8	8·5	

The tank scum was at this time dry and powdery on the top, the fowls having scratched it up.

	Scum.		Sludge.		Gallons of sewage which had passed through the tank.
	Inches.		Inches.		
September 2nd, 1902 :—Inlet end	19·5		9·5	11	6,484,500
Middle	13·5		12·5	11	
Outlet end	11		10	10	
February 9th, 1903 :—Inlet end	24		10·5	7	7,204,500
Middle	20·5		16·5	17·5	
Outlet end	7		16	16·5	
April 30th, 1903 :— Inlet end	15	21	9	12	7,564,500
Middle	13	9	10	10·5	
Outlet end	6	5	(?)	10·5	
June 30th, 1903 :— Inlet end	9	14	13·5	8	7,843,500
Middle	10	5	14·5	15	
Outlet end	10·5	5	16·5	20	

There was at this last date practically no scum over a small part of the right-hand side of the tank.

If these readings of sludge and scum are averaged, we get, roughly :—

	Scum.	Sludge.	Total.	Gallons of Sewage.
	Inches.	Inches.	Inches.	
July 1st, 1902	26	7	33	6,201,000
July 28th, 1902	21	7	28	6,322,500
September 2nd, 1902	15	11	26	6,484,500
February 9th, 1903	17	14	31	7,204,500
April 30th, 1903	11	10·5	21·5	7,564,500
June 30th, 1903	9	14·5	23·5	7,843,500

Such measurements can only be taken as rough approximations, but, allowing for this, it is seen that during the above year of small flow of 4,500 gallons of liquor through the tank per day, the volume of the scum gradually decreased, while that of the sludge increased, the *total volume* diminishing by something like one-third.

June 16th. 1903.—It was now considered advisable to excavate to the bottom round three sides of the filters (it would have been difficult to do this on the side bounded by the channel) and to gradually remove the encasing boards, eventually substituting wire netting for these. If the aeration of the filters had been insufficient hitherto, this might be expected to remedy it. The excavation was accordingly done in the latter part of June, 1903.

June 25th.—The topmost board, 9 inches deep, was removed from three sides.

On June 30th, 1903, the flow through the tank, which at the time was theoretically 4,500 gallons, was re-gauged. It was however found, as the result of five trials, to be about 6,000 gallons (5,200 to 7,200), the flow varying materially with the head of sewage in the manhole. It was thus not satisfactory at the time.

The following were the flows per day during the first fortnight of July :—

	Tank.	Deep Filter.	Shallow Filter.
July 1–9, 1903	4,500	750	375
„ 9–11, „	4,500	1,500	750
„ 12–16, „	18,000		

On July 11th and 13th the flow through the tank was gauged to 18,000 gallons, and on July 16th to 4,500 gallons.

On July 13th it was noted that the scum was getting very thin over nearly the whole of the tank ; the weather had been very warm, and rapid fermentation had been going on. Samples of deep and shallow filter effluent were drawn on that day. These had an earthy smell, but failed to withstand incubation. A further pair of samples, drawn on July 16th, had a slight sewage smell when drawn.

Experiment K. July 17th—Nov. 4th, 1903.

	Tank.	Deep Filter.	Shallow Filter.
Flow through - - - - - - - -	4,500	3,000	1,500
Equivalent to gallons per cube yard per day -	—	125	125

Ten samples of septic tank liquor were partially examined during this period, and gave the figures :—

Parts per 100,000.	*Average.*
Total Nitrogen - - - - - - - - - -	4·04 and 4·29 - - - (2)
"Oxygen absorbed" at 27° C. *at once* - - - - -	0·43 to 0·91 - - - 0·61 (5)
"Oxygen absorbed" *in 4 hours* - - - - - - -	1·92 to 5·32 - - - 3·07 (9)
Solids by centrifuge (vols.) - - - - - - -	8·0 to 26·0 - - - 15·8 (7)
Equivalent, approximately, to solids in suspension - -	— - - about 2·0

The tank liquor was therefore at this time much weaker than before, at least in oxidizable matter as measured by the "oxygen absorbed" test. The rainfall for July, August, and October of this year was very high.

The ten samples of filter effluent examined in each case gave the following figures :—

	Deep Filter Effluent.	Shallow Filter Effluent.
	Average.	*Average.*
Nitrous nitrogen - - - -	0.07 to 0·27— 0·17 (10)	0·05 to 0·28— 0·14 (10)
Nitric Nitrogen* - - - -	0·7 to 2·2 — 1·3 (10)	0·5 to 3·5 — 1·8 (10)
"Oxygen absorbed" at 27° C. *at once*	0·43 to 0·76— 0·59 (5)	0·22 to 0·85— 0·51 (5)
"Oxygen absorbed" at in *4 hours* -	1·41 to 3·02— 2·20 (10)	1·31 to 2·35— 1·62 (9)
Incubator Test (by smell) - - -	8+ (8)	7+ (7)
Solids by centrifuge (vols.) - -	26·0 to 41·0 —33·5 (7)	12·0 to 26·0 —19·2 (7)

The samples of effluent drawn on October 24th, 1903, were analysed more fully than the others, so their figures may be given separately.

Effluent from.	Deep Filter.	Shallow Filter.
Ammoniacal Nitrogen - - - - - - - -	2·24	1.52
Albuminoid Nitrogen - - - - - - - -	—	—
Nitrous Nitrogen - - - - - - - -	0·12	0·12
Nitric Nitrogen - - - - - - - - -	0·99	1·44
"Oxygen absorbed" at 27° C. *at once* - - - -	0·71	0·85
"Oxygen absorbed" in *4 hours* - - - - -	2·29	1·71
Incubation (by smell) - - - - - - -	+	+ †
Dissolved oxygen taken up in 24 hours from (2 vols.) tap water - - - - - - - - - -	0·59	0·35
Solids in Suspension - - - - - - - -	3·1	2·3
Volatile matter in these solids - - - - - -	2·0	1·5
Chlorine - - - - - - - - - -	13·8	—

The above effluents were usually somewhat opalescent and of a brownish tint, with varying amounts of fine brown suspended matter, the deep filter effluent as a rule containing most of this. In one case no notes were made on the day of analysis, but otherwise all the effluents had a clean smell then, and all that were tested (*i.e.*, two thirds of the whole) withstood incubation.

The shallow filter effluents appeared on the whole to be rather better oxidised than the deep.

The effluents of experiment *K* were thus of distinctly better quality than those of any of the preceding experiments, but this was no doubt mainly due to the circumstance that the septic liquor treated was much weaker, owing to the very wet season.

The following notes were made during the progress of experiment K :—

	Scum.	Sludge.	Gallons of sewage which had passed through tank.
July 27th, 1903 :—			
Inlet end of tank - - - -	Practically no scum on the tank, excepting grass roots.		8,028,000
Middle of tank - - - - -			
Outlet end of tank - - - -		23″ to 24″	
August 17th, 1903 :—	—		
Inlet end of tank - - - -	Probably not more than 1″ of scum over about half the surface of the tank.	36″ to 37″	8,190,000
Middle of tank - - - - -		41″ to 38″	
Outlet end of tank - - - -		26″ to 33″	
September 21st and October 1st, 1903	Practically no scum on the tank.		

* Excepting in the case of the two effluents whose analysis has been given in detail, the estimations of nitrate (and in a few instances of nitrite) were made throughout this experiment by the pyrogallic acid method, which is only to be taken as approximately correct.

† Marked as having doubtful smell after incubation, but this cannot have been due to putrescibility.

It will thus be seen that on August 17th the aggregate *thickness* of scum and sludge together was, if anything, rather less than on June 30th. On September 21st rapid fermentation was going on; a few days previously the tank had been covered by scum, but this got broken up by the wind. On October 1st, 1903, the flow through the tank was regauged. On October 13th the second lowest 9″ board was removed from each filter.

On September 21st it was noted that, with the above flow of 125 and 250 gallons per square yard (125 gallons per cube yard), the distribution on to the filters was bad, the shallow filter receiving but little liquor. The latter was readily blocked by leaves—an important point to bear in mind with regard to this method of distribution; thus, on the day in question, a leaf was found at the entrance to this filter, which nearly stopped the flow on to it.

The sewage valve, too, in the entrance channel to the septic tank, was for some days at this time frequently more or less blocked by solid matter.

Experiment L. November 5th, 1903—July 27th, 1904.

	Tank.	Deep Filter.	Shallow Filter.
Flow through *	9,000	6,000	3,000
Equivalent to gallons per cube yard per day	—	250	250

Fifteen samples of septic tank liquor were examined in the course of this experiment. They gave the figures:—

Parts per 100,000.		*Average.*
Total Nitrogen	3·22 to 7·93	5·92 (11)
"Oxygen absorbed" at 27° C. *at once*	0·58 to 2·00	1·28 (13)
"Oxygen absorbed" at 27° C. *in 4 hours*	2·63 to 5·47	4·25 (15)
Solids in suspension	3·15 to 4·9	4·1 (3)
Solids by centrifuge (vols.)	16·4 to 33·0	25·1 (14)

These figures show that the septic tank liquor of this period was much stronger than that of experiment K, though not so strong as in the earlier experiments. The solids in suspension were low throughout (probably about 4 parts per 100,000).

Fifteen samples of effluent from each filter were also examined, with the following results:—

Parts per 100,000.	Deep Filter.			Shallow Filter.		
		Average.			*Average.*	
Ammoniacal Nitrogen	1·83 to 4·64	3·84	(5)	1·72 to 4·00	3·25	(4)
Albuminoid Nitrogen	0·22 to 0·70	0·45	(4)	0·14 to 0·53	0·33	(4)
Nitrous Nitrogen	0·0 to 0·21	0·12	(15)	0·02 to 0·32	0·15	(15)
†Nitric Nitrogen	0·5 to 2·0	0·9	(15)	0·3 to 2·5	1·5	(15)
"Oxygen absorbed" at 27° C. *at once*	0·77 to 1·35	1·04	(13)	0·51 to 1·32	0·89	(13)
"Oxygen absorbed" *in 4 hours*	1·99 to 4·57	3·54	(15)	1·83 to 3·78	2·82	(15)
Incubator test (by smell)		10+ 3−	(13)		11+ 3−	(14)
Dissolved oxygen taken up from (2 to 3 vols.) water at 18° C. in 24 hours	0·56 to 1·75	0·90	(8)	0·54 to 0·98	0·69	(7)
Solids in suspension	5·5 to 7·6	6·4	(3)	3·9 to 7.8	5·9	(3)
Volatile matter in these solids	4·1 to 5·1	4·5	(3)	2·4 to 4·9	3·5	(3)
Solids by centrifuge (vols.)	25·0 to 71·0	47·8	(14)	Trace to 50·0	23·1	(15)
Chlorine	9·8 to 15·0	13·9	(3)	9·8 to 14·8	12·8	(3)

All the above effluents were opalescent liquids of a brownish tinge, and turbid with more or less suspended matter, which was nearly always brown in colour. The deep filter effluent contained as a rule much more suspended solids than the shallow—probably about twice as much, to judge by the centrifuge figures. Excepting three of the deep filter effluents and two of the shallow, which were noted as having a slight sewage or doubtful smell, all the above had a clean smell on the day of analysis.

It will be seen that here again the effluent from the shallow filter was distinctly better oxidized than that from the deep.

The effect of the suspended solids as regards power of taking up dissolved oxygen from water is shown by the following figures:—

Dissolved Oxygen taken up from water in 24 hours at 18° C.

Effluent from	Deep Filter.			Shallow Filter.		
	Suspended Solids.	Original.	Paper-filtered	Suspended Solids.	Original.	Paper-filtered
June 13th, 1904	—	0·66	0·17	—	0·54	0·27
June 22nd, 1904	6·2	0·56	0·28	5·9	0·71	0·23
July 18th, 1904	—	0·78	0·19	—	0·59	0·05
Mean	—	0·67	0·21	—	0·61	0·18

If we compare the results of Experiment L with those of Experiment E (November 29th, 1901, to April 4th, 1902), when the same volumes of tank liquor—6,000 and 3,000 gallons—were being passed through the filters per day, but with a flow of 18,000 gallons through the tank, the great improvement in the effluents of L is manifest. This was undoubtedly due in part to the tank liquor being much weaker in the case of L and containing less suspended solids, and also to the temperature being as a whole higher. Since these factors varied, it is difficult to say whether and how far the removal of the side boards also helped to bring about the improved results, but possibly this assisted too.

The following notes were made during this experiment: On November 6th, 1903, it was observed that the distribution was very bad on to both filters, especially on the deep one, near to a buckled tray; the trays were, therefore, re-set on November 16th, which improved matters somewhat.

On May 27th, 1904, the distribution was good on the shallow filter—better than on the deep, where there was a faulty tray.

On May 30th two more boards were removed from each filter, and on June 8th wire netting was put round them, in order to keep the coke in position. The coke on both filters was very clean.

* Excepting from July 12th–15th, 1904, when the flow was cut off from both tank and filters.
† The nitrate was in this experiment estimated by the pyrogallic acid method, and in a few cases the nitrite also.

The following measurements of scum and sludge were made :—

		Scum.	Sludge.	Gallons of Sewage which had passed through tank.
		Inches.	Inches.	
November 6, 1903.	Inlet End	Only a thin skin over	34 to 33	8,489,160
" "	Middle	about half the surface of	36	—
" "	Outlet End	the tank	39 to 42	—
January 11, 1904.	Inlet End	1·5 to 2	34·5 to 29·5	—
" "	Middle	—	32 to 34	9,083,160
" "	Outlet End	1 to 1·5	36 to 34	—

There was thus a small increase in the thickness of the sludge since the previous August.

First Emptying of the Septic Tank.

On July 27th, 1904, the flow was shut off from the septic tank, and 18 inches of supernatant liquor were removed by a syphon. The scum was at this time very thin—say, an average of about 1 inch over the tank, but much more at the lower end of the tank than at the upper. On July 29th the sludge and scum together measured 3 feet 6 inches to 3 feet 6¾ inches—average 3 feet 6½ inches—all over the tank, measurements being made at ten different positions. On August 4th it was remeasured at the same ten spots, when it varied from 3 feet 3¾ inches to 3 feet 5 inches—average 3 feet 4·3 inches. In the hot weather prevailing at the time the sludge had lost some water by evaporation. At the upper end of the tank the surface layer was now thinner than before, and much gas was being evolved.

Sampling of the Sludge (including the Scum).

In order to get as true a sample of the sludge as possible, for examination in the laboratory, a cylinder of sheet zinc, $\frac{1}{16}$ inch thick, 4 feet long, and 1 foot 6 inches internal diameter, open at both ends, was used ; the edge was so sharp that it cut readily into the sludge. This was lowered gently into the tank at approximately each of the ten different points chosen, so as to give a fair average of the whole, and when it had reached the bottom, the mud in the cylinder was thoroughly stirred up by means of a wooden paddle, so as to get a homogeneous mixture. A sample was then taken from the middle of each cylinder, by means of the dipping tube, the ten samples filling an ordinary pail. The sludge in the pail was again stirred up and re-sampled into bottles, which were put in ice the same evening.

It was found impossible so to immerse the cylinder in the sludge as to have an equal depth of the sludge both inside and out, and this although the cylinder was actually resting on the bottom of the tank in all the dips, excepting possibly the first one. Thus, in the ten dips the inside column of sludge measured less than the whole column by 1½ inches, 1½ inches, 1 inch, 1½ inches, 1¾ inches, 1½ inches, 1½ inches, 1¾ inches, 1¾ inches, and 1¾ inches, *i.e.*, the outside column measured on the average 40·3 inches, and the inside column 38·75 inches. The bottom sludge near the upper end of the tank was very stiff and gritty, but it then became much less dense until about three-quarters down the tank, when the consistency again increased somewhat ; at the outlet end it was much more gelatinous than at the inlet.

The above method of sampling may be recommended as giving a very fair average sample of the sludge of a whole tank, though there is evidently a tendency, in lowering the cylinder, to push a little of the sludge aside. Of course the tank must either be small enough to be spanned by boards, as in this case, or there must be some other way of getting at the sludge.

On August 25th–29th the sludge was removed from the tank and pressed with 25 per cent. of lime, *i.e.*, 5 cwt. of lime went to a ton of pressed cake. With this relatively large proportion of added lime, it pressed easily enough.

That the sludge as a whole had been well digested in the tank is shown by the following experiment :—

On August 8th, 1904, 8·001 grms. sludge were put into a bottle with gas evolution tube attached, the water capacity of bottle and tube together being exactly 400 c c. The bottle and tube were then filled with freshly distilled water (containing probably about 6 c.c. of oxygen per litre), and the outlet end of the narrow evolution tube was led into an inverted receiving tube full of mercury. By September 21st, *i.e.*, in six weeks, only one or two c.c. of gas had been evolved. The sludge, so far as could be judged from this small sample of 8 grms., had thus been exceptionally well digested.

Analysis of the Sludge from the first emptying of the Ilford Experimental Septic Tank.

Two duplicate bottles of sludge, Nos. 1 and 2, were used. Analysis begun August 5th, 1904.

The sludge contained :—

	Per cent.
Moisture	82·68*
Volatile Matter	7·12†
Non-Volatile Matter	10·16‡
	99·96

	Per cent.	
(*a*) "Cellulose," by alkali, acid, and ether	1·84	on the wet sludge.
(*b*) "Cellulose," with previous permanganating	1·21	"
Grit from (*a*)	5·88	"
Grit from (*b*)	5·36	"

Parts per 100,000.

§Ammoniacal Nitrogen	32·9
Albuminoid Nitrogen	114·0
Total organic Nitrogen	436·9
‖Total Nitrogen (by Kjeldahl)	469·8
"Oxygen absorbed" at 27° C. *at once*	736·1
"Oxygen absorbed" at 27° C. *in 4 hours*	2,613·0
¶Dissolved oxygen taken up from water in 24 hours at 20°–21° C.	47·5

This sludge was very black and slimy, and fairly homogeneous. Bottle No. 1, however, contained a piece of clinker which weighed 3·05 grms. (the wet sludge of the bottle weighed 263·25 grms.) ; this clinker was eliminated before the analysis. The sludge also contained several pieces of fibrous matter or wood.

The sludge thus produced, after about 3 years and 2 months' working of the septic tank, at varying rates of flow, was very dense, containing as it did only 82½ per cent. of moisture. The percentage of "cellulose" remaining in it, though not high, bore still a considerable proportion to the whole dry matter. The nitrogenous compounds (equivalent to 2·71 per cent. of nitrogen on the dry substance) are to be regarded as very resistant to further anaerobic action.

On August 31st, 1904, the septic tank was refilled with crude sewage. From that date until August 31st, 1906,** the flow through the tank was, theoretically, 18,000 gallons per day. This period covered the second

* Mean of three estimations, viz.—
(*a*) 82·58 per cent. Done on large sample of No. 1, using rough balance.
(*b*) 83·04 " Done on small sample of No. 1, using fine balance.
(*c*) 82·41 " Done on small sample of No. 2.

† Mean of two estimations—
(*a*) 7·02 per cent. Small sample of No. 1.
(*b*) 7·22 " " " " No. 2.

‡ Mean of two estimations—
(*a*) 9·94 per cent. Done on No. 1.
(*b*) 10·37 per cent. Done on No. 2.

§ 0·2322 grm. of the wet sludge distilled with 500 c.c. water, *i.e.* $\frac{15}{250}$ of 3·8708 grms.

‖ Mean of three estimations—438·0, 500·3, and 471·0. This is equivalent to :—
Nitrogen in wet sludge - - 0·47 per cent.
Nitrogen in the dry matter of the sludge - - 2·71 "

¶ Done on 0·18505 grm. wet sludge in 340 c.c. water.

** Excepting for the five days September 29th to October 3rd, 1904, when there was no flow through.

sludge digestion experiment, which has been reported on separately.* It may just be mentioned, however, that scum commenced to form on the tank on October 26th, 1904, but did not cover the whole tank until February 1st, 1905, five months after the start. By April 1st, 1905, there was a good scum all over it. On July 25th, 1905, *i.e.*, after the tank had run for nearly eleven months, the scum averaged about 15 inches in thickness and the sludge about 5 inches. The scum was very uniform over the whole tank, but rather stiffer at the inlet than at the outlet end.

No analyses were made of filter effluents from Ilford between July 27th, 1904, and April 29th, 1907, but notes were made, mainly by Mr. Chittock, on the appearance of the effluents, and on their keeping properties. These, and the notes upon the filters, may, therefore, be summarized shortly.

July 28th, 1904—April 9th, 1905.—During this time the filters were merely kept moist by being sprinkled once a day.

March 29th, 1905.—The trays on the filters were re-set, and the filters re-boarded.

April 10th—22nd, 1905.

	Deep filter.	Shallow filter.
	gallons.	gallons.
Total daily flow (2 hours) -	about 500	about 250

The filters were run for two hours daily with about half the tank flow, from 9 to 10 a.m. and 4 to 5 p.m. The distribution was not good, and the effluents were very cloudy and smelt badly after keeping for a few days in a full bottle.

April 23rd—June 18th, 1905.

	Deep.	Shallow.
	gallons.	gallons.
Total daily flow (1 hour) -	about 250	about 125

This meant one hour's flow of tank liquor daily.

By the latter date, the effluents had improved considerably. June 16th, the effluent man-holes were cleaned out, about 16 gallons of the liquid deposit being put upon land.

June 19th—Sept. 14th, 1905.

	Deep.	Shallow.
	gallons.	gallons.
Total daily flow (4 hours) -	1,000	500
Equivalent to gallons per cube yard per day - -	42	42

This meant a flow of four hours daily, 9 to 11 a.m. and 3 to 5 p.m.

The effluents apparently went back in quality for a short time, but by the middle of July they had again improved very much. It was noted on July 27th that the distribution on to the shallow filter had improved.

September 15th, 1905—August 31st, 1906.

	Deep.	Shallow.
	gallons.	gallons.
Total daily flow (6 hours) -	1,500	750
Equivalent to gallons per cube yard per day - -	62·5	62·5

This meant a flow of six hours daily, 9 to 12 a.m. and 2 to 5 p.m.

Throughout this period frequent observations were made, for the most part by Mr. Chittock, with regard to the distribution of liquor on to the trays, and to the keeping quality of the effluents. The distribution was nearly always noted as being fair (on October 17th a tray was re-set on the shallow filter, which improved the distribution). The effluents, however, did not, as a rule, keep well, though now and then there was a little improvement in them. During the last six months of this period, an appreciable quantity of leakage water from the large contact bed, about to be mentioned, was getting into the deep filter effluent, more especially (*cf.* p. 239). For some time this leakage water would be poorly purified effluent from a new bed.

It has, however, to be borne in mind that, though the total flow on to the filters at this time was only equivalent to 62·5 gallons of tank liquor per cube yard per day, the filters were actually treating, during their working day of six hours, at the rate of 62·5 × 4 = 250 gallons per cube yard—a very heavy dose. The same remark applies to the preceding period of June 19th to September 14th, 1905.

On December 18th, 1905, and July 17th, 1906, 20 and 24 gallons, respectively, of muddy liquid were removed from the effluent man-holes and put upon the land.

On August 31st, 1906, the septic tank was shut off for cleaning out. The results of this emptying and the degree of sludge digestion during these two years are given in the Memo. on Sludge digestion already referred to (this Appendix, p. 249).

Analysis of the Sludge

The sludge was very carefully sampled while it was being removed from the tank. The following figures of analysis apply to an average sample of it, made up of 58½ sub-samples, taken in equal quantities from each cart-load of 200 gallons, on Sept. 13th—15th, 1906. The sub-samples were kept in ice, and the mixed sample was at once put in ice on reaching the laboratory on the evening of Sept. 15th. There were three bottles of it, A, B, and C., A. being taken from the middle of the mixing vessel employed, and B. and C. from either side of it.

	Bottle A.			Bottle B.		Bottle C.	
Analysis begun - - - - -	Sept. 18th, 1906.			Sept. 20th.		Sept. 21st.	
	a	*b*	*c*	*a*	*b*	*a*	*b*
Total Nitrogen† (by Kjeldahl) - -	510·9	519·1	496·5	532·4	524·5	523·3	518·6
Mean		508·8		528·5		521·0	
"Oxygen absorbed" from $\frac{N}{8}$ Permanganate at 27° C.:— *At once*	667·1	659·0		735·3	737·8	757·1	725·4
Mean	663·1			736·6		741·3	
"Oxygen absorbed" at 27° C. *in 4 hours*	2706·2	2772·1		2813·3	2813·3	2657·0	2643·9
Mean	2739·2			2813·3		2650·5	
Dissolved Oxygen taken up from Water at 18° C.‡ - - - - -	In 3 days. 542·6	553·0		In 4 days. 906·5	760·5	In 3 days. 656·2	644·9
Mean	547·8			833·5		650·6	
Volumes of tap water added for 1 grm. of sludge - - - - -	5174	3105		5704	3422	4703	2822

* *Cf.* Memo. on sludge digestion at Exeter and Ilford, this Appendix, p. 249.

† For the estimation of the Nitrogen and of the "Oxygen absorbed" from Permanganate, about 14 grms. of sludge (14·1729 grm. in one instance) were made up to 1,000 c.c. with water, and the following quantities were taken :–

For Nitrogen (by Kjeldahl) - - - - - - - -	100 c.c.
For "Oxygen absorbed" at once - - - - - - -	25 c.c.
For "Oxygen absorbed" in 4 hours - - - - - -	10 c.c.

It hardly requires to be stated that it is not an easy matter to get even samples from such attenuated mixtures of sludge and water.

‡ The dissolved oxygen used up varied from 13 per cent. to 29 per cent. of the total present.

Gas Evolution Experiment.

In order to ascertain how far this sludge was still capable of giving off gas under anaerobic conditions, a gas evolution experiment, similar to that described on p. 237, was carried out with it.

On Sept. 18th, 1906, 16·658 grms. of the wet sludge (containing 13·89 per cent. of dry matter) were placed in a bottle of 386 c.c. capacity, fitted with a narrow bent side tube, and the bottle and tube were then filled with distilled water (containing 6·0 c.c. of oxygen per litre). The gas evolved was collected in fractions in the usual manner over mercury. Any sulphuretted hydrogen given off with the other gases was, of course, taken up by the mercury, and is therefore not included here.

The following fractions were measured (reduced to 0° C. and 760 m.m. mercury pressure):—

	c.c.
Gas evolved between Sept. 18th and Oct. 18th, 1906 - - - - -	20·2
Gas evolved between Oct. 18th and Dec. 27th - - - - - -	26·2
Gas evolved between Dec. 27th, 1906, and Sept. 27th, 1909 - - -	15·5
Gas remaining in evolution tube, about - - - - - - -	1·0

Total gas from 16·658 grms. sludge = about 64 c.c. (making no correction for the dissolved oxygen in the water taken).

While this sludge was thus not quite so well digested as that from the first emptying of the septic tank (so far as can be judged from the small sample necessarily taken), the volume of gas which it was still capable of giving off under the above conditions was not very great.

From Sept. 15th to Oct. 4th, 1906, the septic tank remained empty. On Oct. 4th it was filled with septic liquor from one of the large tanks on the works, and allowed to stagnate until Dec. 1st. From that date until the close of the experiments the flow through the tank was as follows .—

Dec. 1st and 2nd, 1906 -	About 18,000 galls. per day.
Dec. 3rd - - - - -	" 4,500 " "
Dec. 3rd—31st - -	Tank standing full.
Jan. 1st—3rd, 1907 - -	18,000 galls. per day.
Jan. 3rd—17th - -	Tank standing full.
Jan. 18th—20th, inclusive	18,000 galls. per day.
Jan. 21st—Feb. 1st -	Tank standing full.
Feb. 1st—2nd (one day) -	18,000 galls.
Feb. 2nd—15th - -	Tank standing full.
Feb. 15th—16th (one day)	18,000 galls.
Feb. 16th—23rd - -	Tank standing full.
Feb. 23rd—24th (two days)	18,000 galls. per day.
Feb. 25th - - -	About 4,500 galls.
Feb. 25th—March 11th -	Tank standing full.
March 11th, 1907, to Oct. 31st, 1908 * - - -	18,000 galls. per day.

The Filters.

For about two months from Sept. 1st, 1906, nothing was done to the filters, excepting that from Oct. 10th, at various times, measurements of volume and analyses were made of some leakage effluent which was finding its way from an adjacent large contact bed (brought into operation on March 1st, 1906), on a slightly higher level, to the bottom of the experimental filters, and then passing out of their effluent pipes. Analysis showed this to be a moderately purified effluent, with some brown suspended solid in it. Ten estimations of chlorine gave from 8·80 to 12·48, average = 11·57 parts per 100,000, while two more or less detailed analyses of samples drawn on Nov. 6th, 1906, and Jan. 8th, 1907, gave the following figures :—

Parts per 100,000.	Leakage water from Deep Filter (about 4 gallons per hour on Nov. 6th, 1906, and 1·75 gallons on Jan. 8th, 1907).		Leakage water from Shallow Filter (about 0·5 gallon per hour on Nov. 6th, 1906, and 0·5 gallon on Jan. 8th, 1907.	
Drawn November 6th, 1906, and kept in ice overnight.	Analysed Nov. 7th, 1906.	Analysed Jan. 10th, 1907.	Analysed Nov. 6th, 1906.	Analysed Jan. 10th, 1907.
Ammoniacal Nitrogen - - - - -	2·64	2·9 ap. †	0·17	0·38 ap. †
Albuminoid Nitrogen - - - - -	0·34		0·09	
Nitrous Nitrogen - - - - - -	0·0		0·01	
Nitric Nitrogen - - - - - - -	0·80		2 80	
"Oxygen absorbed" at 27° C. *at once* -	0·19		0·09	
" " " *in 4 hours* -	0·95	0·79	0·63	0·63
Incubator Test (by smell) - - - -	+		+	+
Chlorine - - - - - - - -	12·20	11·14	10·67	8 80
Dissolved oxygen taken up from (2 vols. tap) water in 48 hours at 18° C. - -	0·11		0·10	

The above samples were opalescent and slightly brownish liquids, with a little suspended solid. They had no smell when analysed.

The shallow filter was the farther from the contact bed.

The leakage water amounted in October and the early part of November to 4 to 6 (usually 5) gallons per hour from the deep filter and 0·5 gallon per hour from the shallow filter. The latter quantity was negligible, but it was necessary to lessen the inflow to the deep filter, which was done by digging a trench round the latter on December 20th, and putting in a 3-inch drain pipe. From December 22nd, 1906, to March 11th, 1907, 25 further measurements from the deep filter were made. One gave 2 gallons per hour; twenty-one gave 1¾ gallons; and three gave 1½ gallons. Taking 1¾ as the correct figure, that was equivalent to 42 gallons per day for the deep filter. Another measurement of the leakage water from the shallow filter on January 9th, 1907, again gave 0·5 gallon per hour, equivalent to 12 gallons per day for the shallow filter. These small volumes were practically negligible, in comparison with the volumes of septic tank liquor treated on the filters during 1907–8, and accordingly no account has been taken of them.

Early in December, 1906, new and stronger wire netting (⅛-inch wire) was put round the coke of both filters, and the boards were then replaced and nailed up round the netting. The coke, which had fallen down to some extent, was also put in position again and the trays were re-set.

Nothing further was done with the filters until March 12th, 1907, when the trays were adjusted and tank liquor was run on for 1½ hours, at the rates of 3,000 and 1,500 gallons per day respectively.

The subsequent flows were :—

March 13th to 31st, 1907*	Deep filter.	Shallow filter.
	gallons.	gallons.
Total daily flow (10 hours) -	1,250	625
Equivalent to gallons per cube yard per day - -	125	125

This meant 10 hours flow of tank liquor daily. The distribution was noted as being not good.

No analyses were made of the effluent during this fortnight.

* Flow stopped for 16 hours on May 27th—28th, 1907.

† Approximate; by direct Nesslerization.

The results obtained up to now had shown that, with small experimental filters of fairly even-sized coarse material, 1½ inches to 3 inches in diameter, and with distribution by means of Stoddart trays, it was not possible to get a high-class effluent at Ilford at a reasonable rate of filtration, so long at least as the coke remained fairly clean. The time of contact of liquor with the clean filtering material was evidently too short (for experiments on time of contact, see p. 246). The aeration of the filters was not in fault, at all events not since the boards had been removed from the filters, and, in all probability, not even before then (*cf.* analysis of filter gases, p. 231).

It was therefore decided, at this stage, to try to improve the distribution, and thus to lengthen the time of contact, by replacing the uppermost few inches of coarse by finer material. The top 10 inches and 5 inches, respectively, of the coarse material on (*a*) the deep and (*b*) the shallow filter was therefore removed in the early part of April and replaced by 4 inches (*a*) and 2 inches (*b*) of coke, ½ inch diameter, and 6 inches and 3 inches of coke, ⅜ inch in diameter, the finer material being on the top. All this small coke was washed before it was put on to the filters. On April 13th the trays were replaced, and on the 15th the tank liquor was again turned on to them, as follows :—

Experiment A1, April 15th to May 12th, 1907.

	Deep.	Shallow.
Total daily flow (6 hours)	750 galls.	375 galls.

This meant six hours flow on to the filters daily.

Two samples of tank liquor were examined during this period, and gave :—

	Average.
Total Nitrogen (6·30 and 5·92) -	6·11 (2)
"Oxygen absorbed" in 4 hours (5·28 and 5·40) - - - - - -	5·36 (2)
Solids in Suspension - - - -	5·2 (1)

The tank liquor was thus of moderate strength.

The two pairs of corresponding filter effluents (*a*) and (*b*) gave (in both cases (*b*) was filtered through German paper before analysis) :—

Parts per 100,000.	Deep Filter.		Shallow Filter.	
	Original.	Paper-filtered.	Original.	Paper-filtered.
	(*a*)	(*b*)	(*a*)	(*b*)
Ammoniacal Nitrogen - - - - - - -	2·76	2·46	3·16	3·12
Albuminoid Nitrogen - - - - - - -	0·62	0·28	0·56	0·31
Nitrous Nitrogen - - - - - - -	0·03	0·06	0·03	0·18
Nitric Nitrogen - - - - - - -	2·17	2·14	1·30	1·19
"Oxygen absorbed" at 27°C. *at once* - - -	0·87	0·32	0·78	0·65
" " *in 4 hours* - - -	3·17	1·66	2·97	2·35
Incubation (by smell) - - - - - - -	+	+	+	+
Dissolved Oxygen taken up from water at 18° C. in 6 days - - - - - - - - -	4·32	1·89	3·27	2·50
Solids in suspension - - - - - - -	High.	†	Rather high.	‡
Solids by centrifuge (vols.) - - - - - -	81·3	—	44·2	—

The above effluents were very opalescent and brownish, and they contained much brown suspended solid, which was evidently being washed out of the filters after the rest. Both of the deep filter effluents and the first of the shallow had a faint sewage smell when drawn; the second shallow effluent had an earthy smell. At this time better oxidation was being effected on the deep than on the shallow filter.

Experiment B1. May 15th to 20th, 1907.

	Deep.	Shallow.
Total daily flow on filters (12 hours) -	1,500	750

This meant twelve hours' flow on to the filters daily.

One sample each of tank liquor and of filter effluents were drawn on May 14th. They gave the figures :—

Parts per 100,000.	Tank Liquor.	Deep Filter Effluent.	Shallow Filter Effluent.
Ammoniacal Nitrogen - - - - - -	—	1·84	2·08
Albuminoid Nitrogen - - - - - -	—	0·47	0·49
Total Organic Nitrogen - - - - - -	—	0·57	0·96
Nitrous Nitrogen - - - - - -	—	0·06	0·08
Nitric Nitrogen - - - - - -	—	2·14	1·42
Total Nitrogen (by Kjeldahl) - - - -	5·09	4·61	4·54
"Oxygen absorbed" at 27° C. *at once* - -	1·89	0·80	0·67
"Oxygen absorbed" at 27° C. *in 4 hours* -	5·51	3·18	3·18
Incubation (by smell) - - - - -	—	+	+
Solids in suspension - - - - - -	6·5	8·5	7·3
Chlorine - - - - - - - -	8·97	9·34	—
Dissolved Oxygen taken up from water at 18° C. in 6 days - - - - - -	—	4·3 + x	4·4 + x

These two effluents were the same in appearance and character as the effluents of A1; they had both a soapy smell when drawn.

Experiment C1. May 21st to June 30th, 1907.

From this time onwards the filters were fed continuously, night and day.

	Deep.	Shallow.
Flow on to filters§ - - - - - - - -	1,500	750
Equivalent to gallons per cube yard per day - -	62·5	62·5

* Excepting on March 17th, 24th, and 31st.

† Before filtration through paper, Solids in Suspension = 16·0.

‡ Before filtration through paper, Solids in Suspension = 6·8.

§ Excepting for 16 hours on May 27th–28th.

The five samples of septic liquor drawn during this period gave the following figures :—

Parts per 100,000.		Average.
Total Nitrogen	5·74 to 7·13	6·52 (5)
"Oxygen absorbed" at 27° C. *at once*	2·11 to 3·45	2·77 (5)
"Oxygen absorbed" at 27° C. *in 4 hours*	5·59 to 6·84	6·36 (5)
Solids in suspension	5·1 to 6·4	5·6 (4)
Volatile matter in those solids	4·2 to 5·4	4·5 (4)
Solids by centrifuge (vols.)	11·4 to 42·5	31·0 (4)
Ratio of Solids in suspension to Centrifuge Solids	1 : 2·1 to 1 : 8·2	1 : 5·5 (4)

The tank liquor was thus of about the usual strength. The corresponding samples of filter effluents gave :—

Parts per 100,000.	Deep Filter.	Average.	Shallow Filter.	Average.
Ammoniacal Nitrogen	0·93 to 2·92	1·91 (5)	2·01 to 3·02	2·78 (5)
Albuminoid Nitrogen	0·15 to 0·44	0·33 (5)	0·24 to 0·43	0·35 (5)
Nitrous Nitrogen	0·08 to 0·16	0·12 (5)	0·06 to 0·23	0·14 (5)
Nitric Nitrogen	1·84 to 3·00	2·38 (4)	0·82 to 2·57	1·52 (4)
Total Nitrogen (by Kjeldahl)	4·80 and 5·23	(2)	4·52 and 5·42	(2)
"Oxygen absorbed" at 27° C. *at once*	0·60 to 0·87	0·68 (5)	0·60 to 1·19	0·85 (5)
"Oxygen absorbed" at 27° C. *in 4 hours*	1·63 to 4·23	2·73 (5)	2·20 to 4·46	3·03 (5)
Incubation (by smell)		5+ (5)		5 + (5)
Oxygen in solution	0·05 to 0·36	0·14 (4)	0·05 to 0·09	0·06 (5)
Dissolved Oxygen taken up at 18° C. in 48 hours	0·67 and 1·84	(2)	1·77 and 1·92	(2)
Dissolved Oxygen taken up at 18° C. in 5 days	2·19 to 5·98	4·15 (3)	2·61 to 7·85	5·06 (4)
Solids in suspension	3·0 to 5·1	4·0 (4)	2·8 to 4·9	3·6 (4)
Volatile matter in those Solids	2·3 to 3·8	3·0 (4)	2·0 to 3·8	2·7 (4)
Solids by Centrifuge (vols.)	23·6 to 87·2	49·6 (4)	15·2 to 55·0	38·2 (4)
Ratio of Solids in suspension to Centrifuge Solids	1 : 7·9 to 1 : 17·0	1 : 12·4	1 : 5·2 to 1 : 13·0	1 : 10·6 (4)

All the foregoing effluents, both deep and shallow, were brownish tinted and more or less opalescent, and they contained sometimes—more especially the deep filter effluent—very considerable amounts of light brown and flocculent solids. All had a clean smell—earthy or earthy-fishy, etc.—when analysed. The liquid of the deep filter effluents was twice noted as being clearer than the shallow, and the analysis shows that the former effluents were the better oxidized. Though no one of the effluents failed to withstand incubation, the relatively large amounts of dissolved oxygen which they were capable of taking up in five days showed that, even allowing for the suspended solids present, they were only of moderate quality. Since no analyses were made of effluents in the earlier experiments at the above rate of flow (62·5 gallons per cube yard per day), when there was no fine material on the surface of the filters, no comparison can be drawn with regard to this point.

Experiment D1. July 1st, 1907—January 20th, 1908.

	Deep.	Shallow.
	Gallons.	Gallons.
Flow on to filters	3,000	1,500
Equivalent to gallons per cube yard per day	125	125

Ten samples of septic tank liquor were examined during this period, and gave the following figures :—

Parts per 100,000.		Average.
Total Nitrogen	5.76 to 8·40	6·94 (9)
"Oxygen absorbed" at 27° C. *at once*	1·17 to 4·39	3·34 (10)
"Oxygen absorbed" at 27° C. *in 4 hours*	5.54 to 8.64	7·43 (10)
Solids in suspension	5·3 to 9·2	7·2 (9)
Volatile matter in these solids	4·2 to 6·9	5·7 (9)
Solids by centrifuge (vols.)	31·6 to 80·0	49·5 (10)
Ratio of Solids in suspension to Centrifuge Solids	1 : 5·0 to 1 : 15·0	*1 : 7·4 (9)
Calculated strength (allowing for abnormal ratio between "oxygen absorbed" *at once* and *in 4 hours*)	—	65·4

The above septic liquor was thus of about the usual strength at Ilford—slightly stronger than in the preceding experiment, and with rather more suspended matter.

The corresponding samples of effluent gave :—

Parts per 100,000.	Deep Filter Effluent.	Average.	Shallow Filter Effluent.	Average.
Ammoniacal Nitrogen	1·77 to 5·22	2·76 (10)	2·70 to 5·00	3·52 (10)
Albuminoid Nitrogen	0·22 to 1·20	0·43 (10)	0·25 to 0·82	0·44 (10)
Total Organic Nitrogen	0·50 to 1·33	0·81 (7)	0·46 to 1·20	0·73 (7)
Nitrous Nitrogen	0·07 to 0·33	0·17 (10)	0·06 to 0·42	0·23 (10)
Nitric Nitrogen	0·90 to 3·45	2·00 (10)	0·53 to 1·90	1·28 (10)
Total Nitrogen (by Kjeldahl)	4·84 to 7·22	5·59 (8)	4·50 to 7·10	5·61 (9)
"Oxygen absorbed" at 27° C. *at once*	0·62 to 1·35	0·86 (10)	0·72 to 1·24	0·93 (10)
"Oxygen absorbed" at 27° C. *in 4 hours*	2·13 to 3·73	2·95 (10)	2·42 to 3·93	3·15 (10)
Incubator test (by smell)		10+(10)		9+1−(10)
Oxygen in solution	0·0 to 0·19	0·08 (5)	0·0 to 0·20	0·11 (5)
Dissolved oxygen taken up from water at 18° C. in 48 hours	1·15 to 2·86	2·02 (8)	0·79 to 2·55	1·67 (8)
Dissolved oxygen taken up from water at 18° C. in 5 days	5·00 to 7·80	6·56 (8)	3·96 to 7·97	6·18 (8)
Solids in suspension	3·2 to 9·5	5·9 (9)	3·4 to 6·9	4·1 (9)
Volatile matter in these Solids	2·7 to 6·1	4·3 (9)	2·2 to 5·2	3·9 (9)
Solids by Centrifuge (vols.)	33·0 to 123·0	69·3 (10)	35·0 to 73·5	57·1 (10)
Ratio of Solids in suspension to Centrifuge Solids	1 : 7·1 to 1 : 15·7	1 : 11·9 (9)	1 : 9·0 to 1 : 17·2	1 : 11·9 (9)
Calculated oxidizability	21·5 †		23·0 †	
Units of purification per cube yard	5,488		5,300	

* This ratio was, as a matter of fact, fairly even, only varying in 9 out of 10 estimations between 1 : 5·1 and 1 : 8·7, and in 8 out of 10 estimations between 1 : 5·1 and 1 : 7·3.

† Giving credit for nitrite as well as nitrate.

The last seven of the ten samples each of deep and shallow filter effluent were also examined after paper filtration, with the following results :—

Parts per 100,000.	Deep Filter Effluent.	Average.	Shallow Filter Effluent.	Average.
Ammoniacal Nitrogen	1·78 to 5·23	2·93 (7)	2·66 to 4·99	3·54 (7)
Albuminoid Nitrogen	0·15 to 0·40	0·25 (7)	0·19 to 0·39	0·28 (7)
Nitrous Nitrogen	0·07 to 0·23	0·13 (7)	0·06 to 0·25	0·15 (7)
Nitric Nitrogen	0·90 to 3·45	1 94 (7)	0·53 to 1·90	1·35 (7)
"Oxygen absorbed" at 27° C. *at once*	0·27 to 0·67	0·49 (7)	0·42 to 0·87	0·58 (7)
"Oxygen aborbed" at 27° C. *in 4 hours*	1·33 to 2·23	1·71 (7)	1·78 to 2·67	2·11 (7)
Incubator test (by smell)		4 +, (4)		4 +, (4)
Dissolved Oxygen taken up from water at 18° C. in 48 hrs.	0·46 to 0·79	0·60 (4)	0·60 to 1·02	0·79 (6)
Dissolved Oxygen taken up from water at 18° C. in 5 days	0·54 to 2·97	1·49 (7)	1·02 to 2·50	1·95 (6)

Comparing the *average* figures of the last seven (out of the ten) samples each of deep and shallow filter effluent, before and after filtration through paper, we get the figures :—

Parts per 100,000.	Deep Filter Effluent.		Shallow Filter Effluent.	
	Original.	Paper-filtered.	Original.	Paper-filtered.
Ammoniacal Nitrogen	2·92	2·93	3·55	3·54
Albuminoid Nitrogen	0·47	0·25	0·47	0·28
Nitrous Nitrogen	* 0·13	0·13	0·15	0·15
Nitric Nitrogen	* 1·94	1·94	1·35	1·35
"Oxygen absorbed" *at once*	0·86	0·49	0·86	0·58
"Oxygen absorbed" *in 4 hours*	3·12	1·71	3·09	2·11
Incubation (by smell)	7+	4+ (4)	6+, 1−	4+ (4)
Dissolved oxygen taken up in 48 hours	2·05	0·60 (4)	1·74	0·79 (6)
Dissolved oxygen taken up in 5 days	6·62	1·49	6·49	1·95 (6)
Solids in suspension	6·4	—	5·1	—
Calculated oxidizability†	24·3	9·6	26·0	14·1

All the foregoing effluents, from both deep and shallow filters, were brownish in tint and opalescent, with rather large quantities of suspended solids, which were nearly always brown in colour and finely divided. They all had a clean smell on the day of analysis, though the odour of the shallow effluents was sometimes slightly soapy. The deep filter effluent again contained rather the more suspended solids ; notwithstanding this, it was again a little better oxidized than the shallow effluent. All the deep, and all but one of the shallow, effluents withstood incubation.

On November 19th, 1907, the distribution by the trays was noted as being fairly good, while the fine coke on the top of the filters was clean, without any signs of ponding. On December 18th the distribution was again noted as being fair.

It is difficult to make an exact comparison of the foregoing results with those of experiment K (made before the fine material was put on to the filters), as, owing to the very wet weather of 1903, the strength of the septic liquor in K was only about half what it was in D1. The actual "work done" by the filters in experiment D1 (as calculated by the formulæ given in the memoranda on "Strength of sewage" and "Work done by filters")‡ was not great, viz., 5,488 units by the deep filter and 5,300 by the shallow.

Contrasting the last seven samples each of deep and shallow filter effluent in D1, *after paper filtration*, it is seen that the deep are still rather the better. The latter were fairly good effluents, *per se*, while the shallow might be termed moderate. That the suspended solids of both deep and shallow filter effluents were not very well oxidized is well seen from the third effluent table, the difference in the figures for dissolved oxygen absorption by the original and by the paper-filtered effluents, respectively, being very marked.

Experiment E1. January 21st—June 15th, 1908.

On January 21st two of the 9-inch boards were removed from the upper part of three sides of the deep filter, and one from three sides of the shallow.

	Deep.	Shallow.
Flow on to filters	3,000	1,500
Equivalent to gallons per cube yard per day	125	125

The conditions of experiment E1 were thus the same as those of D1, excepting that now the top quarter of each filter was open to the air on three of its four sides.

The ten samples of septic liquor examined during this period gave the figures :—

Parts per 100,000.		Average.
Total Nitrogen	2·69 to 6·83	5·45 (10)
"Oxygen absorbed" at 27° C. *at once*	1·20 to 3·66	2·07 (10)
"Oxygen absorbed" at 27° C. *in 4 hours*	4·77 to 6·78	5·67 (10)
Solids in Suspension	4·3 to 8·1	6·3 (10)
Volatile Matter in these Solids	3·2 to 6·6	4·9 (10)
Solids by Centrifuge (vols.)	20·8 to 43·4	33·3 (10)
Ratio of Solids in Suspension to centrifuge solids	1 . 2·9 to 1 : 7·9	1 : 5·3 (10)
Calculated strength (allowing for abnormal ratio between "oxygen absorbed" *at once* and in *4 hours*)		54 6

The above septic liquor was thus only five-sixths as strong as that of experiment D1, and it also contained rather less suspended solids. This was not due to increased rainfall, the period of E1 being much drier than that of D1.

* Throughout these experiments and the following ones, only one estimation was made of nitrite and nitrate in each case.

† Taking the organic nitrogen as twice the albuminoid, and allowing for nitrite as well as nitrate ; the nitrous nitrogen is multiplied by the round factor 2·0.

‡ This Appendix, pp. 4 and 12.

The corresponding samples of effluent gave :—

Parts per 100,000.	Deep Filter Effluent.		Shallow Filter Effluent.	
		Average.		Average.
Ammoniacal Nitrogen	1·48 to 3·31	2·53 (10)	1·96 to 3·92	2·95 (10)
Albuminoid Nitrogen	0·27 to 0·60	0·35 (10)	0·26 to 0·39	0·33 (10)
Total Organic Nitrogen	0·59 to 0·93	0·80 (9)	0·37 to 0·82	0·67 (9)
Nitrous Nitrogen	0·09 to 0·55	0·20 (10)	0·05 to 0·25	0·14 (10)
Nitric Nitrogen	0·69 to 2·98	1·77 (10)	0·51 to 1·85	1·13 (10)
Total Nitrogen (by Kjeldahl)	4·32 to 5·94	5·23 (10)	4·19 to 5·52	4·99 (9)
"Oxygen absorbed" at 27° C. *at once*	0·54 to 1·04	0·79 (10)	0·45 to 1·01	0·76 (10)
"Oxygen absorbed" at 27° C. *in 4 hours*	1·94 to 3·62	2·95 (10)	2·55 to 3·61	2·96 (10)
Incubator test (by smell)		10 + (10)		8 +, 1(?), 1 −, (10)
Dissolved Oxygen taken up from water at 18° C. in 48 hours	0·97 to 3·33	*2·25 (9)	0·80 to 4·01	*2·00 (10)
Dissolved Oxygen taken up from water at 18° C. in 5 days	3·06 to 13·00	†7·20 + x (9)	3·10 to 10·00	‡5·75 + x (10)
Solids in Suspension	4·8 to 8·6	6·3 (10)	3·6 to 7·8	5·0 (10)
Volatile Matter in these Solids	3·2 to 5·4	4·3 (10)	2·5 to 4·8	3·5 (10)
Solids by Centrifuge (vols.)	40·0 to 78·0	58·1 (10)	24·8 to 61·6	43·2 (10)
Ratio of Solids in Suspension to Centrifuge Solids	1 : 7·2 : 1 to 12·2	1 : 9·2 (10)	1 : 5·5 to 1 : 13·5	1 : 8·7 (10)
Calculated Oxidizability §	21·9		22·6	
Units of Purification	4,088		4,000	

All the ten samples of effluent, in each case, were also analysed after filtration through paper, with the following results :—

Parts per 100,000.	Deep filter effluent.	Shallow filter effluent.
	Average.	Average.
Ammoniacal Nitrogen	1·48 to 3·30—2·52 (10)	1·96 to 3·92—2·96 (10)
Albuminoid Nitrogen	0·16 to 0·28—0·22 (10)	0·18 to 0·31—0·23 (10)
Total Organic Nitrogen	0·35 to 0·64—0·50 (7)	0·28 to 1·05 —0·53 (7)
Nitrous Nitrogen	0·09 to 0·55—0·20 (10)	0·05 to 0·25—0·14 (10)
Nitric Nitrogen	0·69 to 2·98—1·77 (10)	0·51 to 1·85—1·13 (10)
Total Nitrogen (by Kjeldahl)	4·55 to 5·61—4·92 (8)	3·90 to 5·89—4·92 (9)
"Oxygen absorbed" at 27° C. *at once*	0·36 to 0·67—0·52 (10)	0·41 to 0·67—0·53 (10)
"Oxygen absorbed" at 27° C. *in 4 hours*	1·32 to 2·08—1·57 (10)	1·50 to 2·45—1·83 (10)
Incubator test (by smell)	10+, (10)	10+ (10)
Dissolved Oxygen taken up from water at 18° C. in 48 hours	0·34 to 1·83—*0·91 (9)	0·26 to 2·40—‖0·96 (10)
Dissolved Oxygen taken up from water at 18° C. in 5 days	0·98 to 6·36— 2·93 (9)	1·05 to 5·82—2·94 (9)
Calculated Oxidizability	7·9	12·0

Comparing the average figures of the ten samples, both of deep and shallow filter effluent, before and after filtration through paper, we get the figures¶ :—

Parts per 100,000.	Deep filter effluent.		Shallow filter effluent.	
	Original.	Paper-filtered.	Original.	Paper-filtered.
Ammoniacal Nitrogen	2·53	2·52	2·95	2·96
Albuminoid Nitrogen	0·35	0·22	0·33	0·23
Total Organic Nitrogen	0·80 (9)	0·50 (7)	0·67 (9)	0·53 (7)
Nitrous Nitrogen	0·20	0·20	0·14	0·14
Nitric Nitrogen	1·77	1·77	1·13	1·13
Total Nitrogen	5·23	4·92 (8)	4·99 (9)	4·92 (9)
"Oxygen absorbed" at 27° C. *at once*	0·79	0·52	0·76	0·53
"Oxygen absorbed" at 27° C. in *4 hours*	2·95	1·57	2·96	1·83
Incubator test (by smell)	10 +	10 +	8 +, 1 (?) 1 −	10 +
Dissolved Oxygen taken up at 18° C. in 48 hours	2·25 (9)	0·91 (9)	2·00	0·96
Dissolved Oxygen taken up at 18° C. in 5 days	7·20 + x (9)	2·93 (9)	5·75 + x	2·94 (9)
Solids in Suspension	6·3	—	5·0	—
Calculated Oxidizability	21·9	7·9	22·6	12·0

All the effluents of Experiment E1, both deep and shallow, were of a brownish tint, and practically all were opalescent. The suspended solids were brown, excepting in the case of the first deep filter effluent, when they were black. The first and ninth of the deep filter effluents had a strong and slight sewage smell, when they came to be analysed, but all the others—both deep and shallow—a clean smell. It will be noted that, as in Experiment D1, the deep filter effluent contained rather more suspended matter than the shallow. All the deep filter effluents, and all but one of the shallow, withstood incubation. The deep were again rather the better oxidized.

Frequent notes were made in the course of this experiment to the effect that the distribution from the trays was fair over the whole time, and that there was no sign of ponding on either of the filters, the coke remaining clean.

Comparing the results of Experiments D1 and E1, we see that though the tank liquor treated was weaker in the latter case, the effluents—apart from suspended solids—

* Taking, in two instances, two-thirds of the absorption in 3 days.
† This figure is slightly under the reality ; the oxygen was exhausted in two cases.
‡ Oxygen exhausted in one case.
§ Giving credit for nitrite as well as for nitrate.
‖ Taking, in two instances, two-thirds of the absorption in three days.
¶ These represent the average of ten estimations, excepting where otherwise noted in brackets.

contained rather larger amounts of readily oxidizable matter, and were therefore not quite so good. The aggregate work done by the filters in E1 was also distinctly less than in D1, about four-fifths, viz. :—4,088 units by the deep filter and 4,000 by the shallow. The average air temperature was higher during D1 than during E1.

Experiment E1 no doubt covered the period of the "Spring out-flush," of solids from the filters, which always tends to lower the quality of effluents while it lasts. It may, however, be taken broadly that the removal of the top boards from the filters had no beneficial effect upon the quality of the effluents. The suspended solids of the effluents in Experiment E1 again contained much oxidizable matter.

Experiment F1. June 18th—October 31st, 1908. *

On June 16th and 17th the filters were put out of action while three more boards were being removed from the deep filter and one from the shallow. Excepting, therefore, for one board at the bottom of each, the filters were now open to the air on three of their four sides. Apart from differences of season and temperature, this was the only point in which Experiment F1 differed from Experiments E1 and D1.

	Deep.	Shallow.
Flow on to filters - - - - -	3,000	1,500
Equivalent to gallons per cube yard per day - - - - -	125	125

The eight samples of septic liquor examined during this period gave the figures :—

Parts per 100,000.		*Average.*
Total Nitrogen - - - - - - - - - - - -	4·83 to 8·09 - -	6·76 (8)
"Oxygen absorbed" at 27° C. *at once* - - - - - - -	1·90 to 4·80 - -	3·74 (8)
"Oxygen absorbed" at 27° C. in *4 hours* - - - - - -	4·77 to 8·62 - -	6·99 (8)
Solids in suspension - - - - - - - - - -	4·2 to 9·9 - -	6·7 (8)
Volatile matter in these solids - - - - - - -	3·7 to 5·9 - -	5·1 (8)
Solids by centrifuge (vols.) - - - - - - - -	28·8 to 59·5 - -	37·9 (8)
Ratio of solids in suspension to centrifuge solids - - -	1 : 4·1 to 1 : 7·1 - -	1 : 5·7 (8)
Calculated strength (allowing for the abnormal ratio between "Oxygen absorbed" *at once* and in *4 hours*).	—	57·6

The septic liquor was thus rather stronger than in Experiment E1, and distinctly stronger as regards nitrogenous matter ; the suspended solids were only a trifle higher. The carbonaceous matter of the sewage had evidently been digested to a greater extent this time in the septic tank, no doubt because of the higher temperature for part of the time. The difference in strength of tank liquors F1 and E1, while only nominal by calculation, was probably rather greater in reality, since the nitrogen oxidation stage in biological filtration is apparently more difficult than the carbon oxidation stage.

The corresponding effluents gave :—

Parts per 100,000.	Deep Filter Effluent.	Average.	Shallow Filter Effluent.	Average.
Ammoniacal Nitrogen - - - - - - -	1·34 to 3·07	2·35 (8)	2·59 to 4·08	3·30 (8)
Albuminoid Nitrogen - - - - - -	0·24 to 0·43	0·31 (8)	0·27 to 0·49	0·36 (8)
Total Organic Nitrogen - - - - - - -	0·37 to 1·39	0·81 (8)	0·48 to 0·72	0·58 (4)
Nitrous Nitrogen - - - - - - - -	0·12 to 0·33	0·20 (8)	0·10 to 0·50	0·29 (8)
Nitric Nitrogen - - - - - - - -	1·51 to 2·58	2·16 (8)	0·93 to 2·30	1·46 (8)
Total Nitrogen (by Kjeldahl) - - - - - -	3·81 to 6·53	5·52 (8)	3·78 to 6·39	5·36 (8)
"Oxgen absorbed" at 27° C. *at once* - - - -	0·65 to 1·16	0·76 (8)	0·68 to 1·10	0·86 (8)
"Oxygen absorbed" at 27° C. in *4 hours* - - -	2·35 to 3·38	2·66 (8)	2·29 to 3·41	2·86 (8)
Incubator test (by smell) - - - - - - -		8 + (8)		8+(8)
Dissolved Oxygen taken up from water at 18° C. in 48 hours - - - - - - - - - -	0·45 to 1·89	1·52 (8)	0·55 to 7·7+x§	1·97+x (8)
Dissolved Oxygen taken up from water at 18 °C. in 5 days	4·50 to 8·25	‡6·47+x (8)	3·20 to 16·2+x‖	6·55+x (8)
Solids in Suspension - - - - - - - -	4·7 to 13·1	7·4 (8)	3·9 to 10·7	6·0 (8)
Volatile matter in these Solids - - - - - -	3·5 to 7·5	4·8 (8)	2·9 to 6·0	3·9 (8)
Solids by Centrifuge (vols.) - - - - - - -	29·8 to 98·4	65·2 (7)	24·4 to 98·4	54·5 (8)
Ratio of Solids in Suspension to Centrifuge Solids -	1:3·9 to 1:14·5	1:7·7 (7)	1:6·1 to 1:10·7	1:9·1 (7)
Calculated Oxidizability (giving credit for the nitrite as well as for the nitrate) - - - - - - -		22·1		26·1¶
Units of purification - - - - - - - -		4,438		3,938

* Tank liquor shut off for 14 hours on July 24th.

† In two cases, two-thirds of three days.

‡ In one case, five-sixths of six days. Oxygen exhausted in one instance.

§ Or, excluding one very high figure, 0·55 to 1·72 = 1·15 (7). In two cases, two-thirds of two days.

‖ Or, excluding one very high figure, 3·20 to 7·20 +x= 5·17 + x (7). In one case, five-sixths of six days Oxygen exhausted in two instances.

¶ Taking the Organic Nitrogen as being twice the Albuminoid.

All the eight samples of effluent, in each case, were also analysed after filtration through paper, with the following results :--

Parts per 100,000.	Deep Filter Effluent.		Shallow Filter Effluent.	
		Average.		Average.
Ammoniacal Nitrogen	1·34 to 3·08	2·36 (8)	2·55 to 4·08	3·30 (8)
Albuminoid Nitrogen	0·12 to 0·24	0·17 (8)	0·17 to 0·40	0·26 (8)
Total Organic Nitrogen	0·19 to 1·08	0·49 (7)	0·22 to 0·70	0·37 (4)
Nitrous Nitrogen	0·12 to 0·33	0·20 (8)	0·10 to 0·50	0·29 (8)
Nitric Nitrogen	1·51 to 2·58	2·16 (8)	0·93 to 2·30	1·47 (8)
Total Nitrogen (by Kjeldahl)	3·62 to 6·29	5·27 (8)	3·75 to 6·24	5·15 (7)
"Oxygen absorbed" at 27° C. *at once*	0·27 to 0·61	0·43 (8)	0·35 to 0·70	0·58 (8)
"Oxygen absorbed" at 27° C. *in 4 hours*	1·17 to 1·69	1·37 (8)	1·57 to 2·00	1·81 (8)
Incubator test (by smell)		8+ (8)		8+ (8)
Dissolved Oxygen taken up from water at 18° C. in 48 hours	0·21 to 0·43	*0·30 (8)	0·07 to 0·55	*0·39 (8)
Dissolved Oxygen taken up from water at 18° C. in 5 days	0·54 to 1·70	†0·86 (8)	1·05 to 1·73	‡1·31 (8)
Calculated Oxidizability (crediting nitrite as well as nitrate)		5·9		12·2§

Comparing the average figures of the foregoing eight samples, both of deep and shallow filter effluent, before and after filtration through paper, we get the figures|| :—

Parts per 100,000.	Deep Filter Effluent.		Shallow Filter Effluent.	
	Original.	Paper Filtered.	Original.	Paper Filtered.
Ammoniacal Nitrogen	2·35	2·36	3·30	3·30
Albuminoid Nitrogen	0·31	0·17	0·36	0·26
Total Organic Nitrogen	0·81	0·49 (7)	0·58 (4)	0·37 (4)
Nitrous Nitrogen	0·20	0·20	0·29	0·29
Nitric Nitrogen	2·16	2·16	1·47	1·47
Total Nitrogen (by Kjeldahl)	5·52	5·27	5·36	5·15 (7)
"Oxygen absorbed" at 27° C. *at once*	0·76	0·43	0·86	0·58
"Oxygen absorbed" at 27° C. *in 4 hours*	2·66	1·37	2·86	1·81
Incubator Test (by smell)	8+	8+	8+	8+
Dissolved Oxygen taken up at 18° C. in 48 hours	1·52	0·30	1·97 + x	0·39
Dissolved Oxygen taken up at 18° C. in 5 days	6·47 + x	0·86	6·55 + x	1·31
Solids in suspension	7·4	—	6·0	—
Calculated Oxidisability	22·1	5·9	26·1	12·2

All the foregoing samples of effluent were brownish and opalescent or fairly clear, with varying and often large quantities of suspended solids, and all of them—excepting possibly the shallow filter effluent of October 6th—had a clean smell on the day of analysis. The effluents from the deep filter again contained the larger quantity of solids—an average of 7·4 parts, as against 6 parts in the shallow. Every one of the effluents, deep and shallow, withstood incubation.

Only two notes regarding the distributions were made, at the middle and end of the experiment, but it was evidently fairly good throughout, and there was no sign of any ponding on the filters.

It has been already stated that the septic liquor of this experiment was stronger than that of experiment E1—probably appreciably stronger.

The effluents from the deep filter were distinctly better oxidized than those from the shallow, but both of them—apart from their suspended solids—were of very fair quality *per se*. The aggregate work done by the filters amounted to 4,438 units by the deep filter and 3,938 by the shallow. This showed an improvement on E1 as regards the deep filter, while the work done by the shallow filter remained the same.¶ It cannot be said that the removal of the boards, so as to give a filter open on three sides, had any appreciable influence on the purification effected. True, the septic liquor treated was this time stronger than during experiment E1, but on the other hand there was a good deal of very warm weather (though with heavy rains in July and August) during the period covered by F1, and there was of course no spring outflush of solids.

The oxidizable character of the suspended solids of both effluents was even more marked during this than during the earlier experiments.

Throughout the whole of the experiments at Ilford the coke remained clean, excepting that there was some ponding on the deep filter during experiment E (April, 1902). There was never any accumulation of fine solids in the filtering material.

These latter filtration experiments at Ilford showed how much the quality of the effluents had been benefited by putting fine material on the top of the filters, and so improving the distribution through the whole mass.

* In two cases, two-thirds of three days.
† In two cases, five-sixths of six days.
‡ In one case, five-sixths of six days.
§ Taking the Organic Nitrogen as being twice the Albuminoid.
|| These represent the average of eight estimations, excepting when otherwise noted in brackets.
¶ It must not be forgotten that a strict comparison of the work done by a filter during two periods of time can only be drawn if the liquor, in passing through the filter, has the same length of contact in both cases (*cf.* salt experiment, p. 246). The coke on the filters at Ilford, however, remained to all appearance quite clean throughout the experiments, excepting that the top of the deep filter was ponded in some places during the early experiment E, in 1902. The above comparative figures for work done may therefore, we think, be accepted as correct, so far as this point is concerned.

Still, though non-putrescible and fairly well oxidized effluents were now obtained, with a flow on to the filters of 125 gallons per cube yard per day of septic liquor of about medium strength, they never reached a very high degree of purity, nor was the oxidizing work done by the filters more than about half what can be reasonably looked for from percolating filters under suitable conditions (*cf.* the Reports on Experiments at Accrington, Dorking, and Rochdale, and on "Estimation of Work done by Sewage Filters," in this Appendix).

It is obvious, from a theoretical point of view, that, given sufficient aeration, the degree of purification to be obtained from a sewage filter must depend upon the length of time during which the sewage liquor is in contact with the matured filtering material. In order to get an approximate relative measure of this "time of contact" on percolating filters, careful observations were made, both at Ilford and elsewhere, on the time required by a given quantity of solution of common salt of known strength to pass through the filters. A systematic experiment of this kind was carried out for the Commission by Mr. C. C. Frye, at Bradford, in the year 1904, and so far as we are aware, this was the first time that the plan was tried. Even though a solution of sodium chloride, of which very little would be "adsorbed" by filter material, is not the same thing as a sewage liquor containing compounds of ammonia and colloidal substances, the different rates at which salt solution passes through material of different sizes may not unreasonably be regarded as more or less analogous to the rates at which sewage will pass.

A large number of these salt experiments were made at Dorking, and full details of the *modus operandi* there, and of the results obtained, have been given by Mr. Richards in the report on the Dorking experiments in this Appendix. Two or three were carried out at Ilford by Mr. A. F. Girvan; the last, done on January 9th, 1908, was naturally the best, and it may therefore be described shortly.

About 7 to 8 lbs. of salt were dissolved in a little more than two gallons of water, and the solution was then slowly siphoned into the small distribution manhole near the filters (in which the flow of tank liquor was divided on to the deep and shallow filters), with thorough stirring. The total flow of tank liquor through the two filters was at the rate of 4,500 gallons per day (3,000 + 1,500), or 3 gallons per minute. The delivery of the two gallons of salt solution into the septic liquor took 2⅓ minutes, and therefore the addition of this solution increased the rate of flow to 4 gallons per minute for about two minutes. The rectangular cemented man hole in the channel between the deep and shallow filters was covered, as in the preceding salt experiment, with a piece of sheet iron.

Samples of the filter effluents were drawn at the intervals specified in the appended table, and the chlorine in these samples was estimated by direct titration.

January 9th, 1908.	Time of Day.	Length of time since Salt was introduced.		Chlorine found in		
				Deep Filter Effluent.	Shallow Filter Effluent.	
	a.m.	Hours.	Min.	Parts per 100,000		
Salt introduced - - -	11.40 to 42⅓			7·8	7·8	
„ „	11.44	0	4	8·4	10·0	
„ „	11.45	0	5	10·8	27·2	
„ „	11.46	0	6	20·7	48·5	
„ „	11.47	0	7	35·5	77·0	
„ „	11.48	0	8	57·0	95·5	1-Minute Intervals.
„ „	11.49	0	9	77·5	107·0	
„ „	11.50	0	10	91·0	104·2	
„ „	11.51	0	11	99·6	105·0	
„ „	11.52	0	12	110·4	102·0	
„ „	11.53	0	13	117·4	102·0	
„ „	11.54	0	14	124·0	99·5	
„ „	11.55	0	15	122·0	96·6	
„ „	11.58	0	18	123·6	90·0	
„ „	12.1	0	21	113·0	82·0	
„ „	12.4	0	24	104·0	75·0	3-Minute Intervals.
„ „	12.7	0	27	94·0	69·5	
„ „	12.10	0	30	84·6	65·0	
„ „	12.13	0	33	79·0	61·0	
„ „	12.18	0	38	70·0	55·0	
„ „	12.23	0	43	63 0	52·0	
„ „	12.28	0	48	58·5	49·0	5-Minute Intervals.
„ „	12.33	0	53	53·5	45·0	
„ „	12.38	0	58	49·0	42·5	
„ „	12.43	1	3	45·5	41 0	
„ „	12.58 a.m.	1	18	35·5	35·0	
„ „	1.13 p.m.	1	33	31·0	32·0	
„ „	1.28	1	48	26·8	29·6	15-Minute Intervals.
„ „	1.43	2	3	24·4	26·4	
„ „	1.58	2	18	22·4	26·0	
„ „	2.13	2	33	20·4	26·4	
„ „	2.45	3	5	18·0	17·6	½-Hour Interval.
„ „	3.45	4	5	16·6	15·8	1-Hour Interval.

The results are given in the accompanying table.* It will be seen that they are very similar for the two filters. At the very beginning the salt issued more quickly from the shallow filter, but by the end of the first hour a rather greater proportion had come through the deep filter.

The samples were not continued for a sufficient length of time to allow of an exact calculation of the "time of contact," the chlorine in both effluents at the end of the experiment being still about twice the normal, viz., 16·6 and 15·8 parts per 100,000. Assuming, however, that the whole of the salt would have been out of the filters in rather more than 4 hours, the *average* times of contact, as judged by the figures for chlorine, come to 0·96 hour for the deep filter and 1·1 hours for the shallow filter, *i.e.*, approximately one hour in each case.

This is considerably less than the time of contact obtained with filters of coarse material in the Dorking experiments, where something like 2 to 2½ hours average contact would have been given for the same rate of filtration. It is thus clear that the rate of percolation through the Ilford filters at this time, and it may safely be said all through the experiments, was rather too great to allow of the production of high-class effluents. It should be remembered also that the Ilford septic liquor was fairly strong, and that it contained a good deal of sulphureted hydrogen.

These experiments therefore point to the advisability, when filling with coarse material a filter which is not very deep, of having that material *not* too even in size, as otherwise the spaces between the individual pieces may be too great, with the result that the passage of the sewage liquor is not sufficiently retarded. All through these experiments the effluent solids passed very readily through the filters, rather too readily, in fact, for their thorough oxidation, while the interstices of the coke apparently never got sufficiently filled up with semi-solid matter to retard the flow through the filter to the degree necessary for the perfect oxidation of a septic liquor of medium strength, distributed by means of trays.

* A diagram illustrating the results is published in the Fifth Report of the Commission (facing page 73).

That there ought to be a free base to a percolating filter, *i.e.*, a base which affords thorough drainage and offers no resistance to the free circulation of air, is now universally allowed. Mr. Stoddart pointed this out at the very beginning of the experiments. The drains of the experimental filters at Ilford were so large, relatively to the size of the filters, that the base might reasonably be looked upon as a free base; still, it would probably have been better had it been made absolutely open.

The main conclusions to be drawn from these experiments are, we think :—

1. That a domestic sewage of medium strength, passing through a septic tank at a 24 hours' rate of flow (which, of course, gradually accelerates as the sludge in the tank increases), will for two years give a digestion of something like 30 per cent. of the suspended solids of the sewage, or, making a correction for colloidal matter, a digestion of about 25 per cent.

The relatively large proportion of sulphuretted hydrogen in the Ilford septic liquor, as judged by its odour and by the high ratio of the figure for "oxygen absorbed" at once to that for "oxygen absorbed" in 4 hours, leads to the conclusion that a quicker rate of flow than 24 hours would be advisable, provided that the solids were sufficiently settled.

2. Throughout these experiments there was never very much difference in quality between the deep and the shallow filter effluents, though the deep were usually rather the better oxidized of the two, and this, although the deep filter possibly got rather more than its proportionate share of tank liquor. The reason for this somewhat better oxidation no doubt was that, in a deep filter, inequalities of distribution are better neutralized than in a shallow one. Given thorough aeration, good distribution, and sufficient time of contact of the sewage liquor with the filtering material, it would make little or no difference whether filters of medium to coarse material were built deep or shallow. But since no method of distribution is perfect, and since unequal distribution means uneven length of contact, it is inadvisable to construct such filters very shallow.

3. The distribution of the tank liquor on to the filters by means of Stoddart trays was found to be much more efficient at high than at low rates of filtration per square yard. With low rates of filtration per square yard the distribution could not be considered good; it can, however, be very greatly improved by the simple device of putting some fine material on the top of the filter.

4. In the earlier experiments the filters were filled with coarse material only, but in the later ones they had a little fine material on the top, to assist the distribution. In the first half of each series the filters were (*a*) completely boarded in, while in the second half the boards were (*b*) gradually removed until the filters were left entirely open to the air on three sides. Unfortunately, for one reason or another, it was not often possible to draw an exact comparison between the filtration results of (*a*) and (*b*), so as to be able to say definitely whether the exposure of the sides to the air was beneficial or not. In the earlier experiments this did seem to have a good effect, but in the later ones—when effluents of better quality were being produced—the effect did not seem to be appreciable. So far, therefore, as the results go, it does not appear to make much difference, in the purification effected by a small filter of coarse material and of moderate depth, whether the sides are open or not, provided the base is free.

Although this Report is only signed by myself, a very considerable share of the work involved in it really falls to my colleagues, Mr. C. C. Frye and Mr. G. B. Kershaw. Though this applies more especially to the experiment on septic tank digestion (1904–6), it holds good for other points also.

In conclusion, I should like to offer my cordial thanks to Mr. H. Shaw, A.M.I.C.E., Surveyor to the Ilford Urban District Council, and Mr. Percy Taylor, A.M.I.C.E. (now Surveyor to the District Council at Hampton Wick), for their willing help and co-operation throughout the experiments. To Mr. H. Chittock, Works Manager, the general superintendence of the experiments and the taking of the daily records were entrusted, and I cannot speak too highly of the thorough and reliable manner in which he carried out his duties. I would also beg to offer him my best thanks.

From the commencement to the end of the experiments Mr. Chittock kept daily records, taken at 8 a.m. and 4 p.m., of :—

(*a*) Depth of sewage at large manhole, a short distance above the entrance to the septic tank.
(*b*) Temperature of sewage at large manhole.
(*c*) ,, ,, sewage entering septic tank.
(*d*) ,, ,, septic liquor leaving tank.
(*e*)* ,, ,, septic liquor going on to deep filter.
(*f*) ,, ,, septic liquor going on to shallow filter.
(*g*) ,, ,, effluent from deep filter.
(*h*) ,, ,, effluent from shallow filter.
(*i*) ,, ,, air.
(*j*) ,, ,, air, maximum and minimum.
(*k*) Rainfall (noted 8 a.m.)

These figures have been averaged and tabulated. A very short summary of the respective average figures is given in the subjoined Appendix to this report; but the original records, together with a much more detailed summary, can be seen at the office of the Commission by any one interested in the subject.

GEORGE McGOWAN.

December, 1909.

* *e*, *f*, *g* and *h*, of course, only when the filters were working.

APPENDIX TO ILFORD REPORT.

Temperature Observations (Fahrenheit Scale), &c.

	Length of time covered by observations.	Summary of Averages. Extreme readings.		Extremes of Averages. 8 a.m.		Extremes of Averages. 4 p.m.		Maximum Variation over the whole time.
Temperature of sewage at large manhole in Works	Aug. 1901 to Aug. 1906.	44·2° Feb. 1902.	62·3° Aug. 1901.	47·0° Mar. 1902. Jan. 1905.	61·2° Aug. 1906.	47·3° Feb. 1902.	62·4° Aug. 1906.	18·1°
Temperature of sewage entering tank - - -	Aug. 1901 to Aug. 1906.	43·0° Jan. 1905.	64·5° July 1904.	46·0° Feb. 1902.	62·5° Aug. 1901. Aug. 1906.	47·1° Feb. 1902.	62·6° Aug. 1906.	21·5°
Temperature of Liquor leaving tank - - -	Aug. 1901 to Aug. 1906.	42·0° Jan. 1904.	66·0° July 1904.	44·7° Feb. 1904.	62·3° Aug. 1906.	45·2° Feb. 1904.	62·6° Aug. 1906.	24·0°
Temperature of Liquor leaving tank - - -	Aug. 1901 to June 1902.	44·7° Feb. 1902.	63·1° Aug. 1901.	44·7° Feb. 1902.	62·3° Aug. 1901.	45·0° Feb. 1902.	63·1° Aug. 1901.	18·4°
Temperature of Liquor going on to deep filter -	Aug. 1901 to June 1902.	42·7° Feb. 1902.	64·2° Aug. 1901.	44·8° Feb. 1902.	61·4° Aug. 1901.	44·8° Feb. 1902.	62·2° Aug. 1901.	21·5°
Temperature of Liquor going on to shallow filter	Aug. 1901 to June 1902.	42·5° Feb. 1902.	64·3° Aug. 1901.	44·3° Feb. 1902.	61·6° Aug. 1901.	44·7° Feb. 1902.	62·2° Aug. 1901.	21·8°
Temperature of effluent from deep filter - -	Aug. 1901 to June 1902.	41·5° Feb. 1902.	66·1° Aug. 1901.	43·3° Feb. 1902.	61·6° Aug. 1901.	44·3° Feb. 1902.	63·0° Aug. 1901.	24·6°
Temperature of effluent from shallow filter - -	Aug. 1901 to June 1902.	39·2° Feb. 1902.	66·2° Aug. 1901.	41·6° Feb. 1902.	60·6° Aug. 1901.	42·6° Feb. 1902.	63·2° Aug. 1901	27·0°
Temperature of Air - - - - - -	Aug. 1901 to Oct. 1908.	19·6° Jan. 1908.	90·6° Sept. 1906.	33·5° Feb. 1902.	65·8° July 1904. July 1905.	38·4° Feb. 1902.	74·4° July 1905.	71·0°
Maximum day and night Temperatures - -	Aug. 1901 to Oct. 1908.	28·6° Jan. 1907.	94·0° Sept. 1906.	42·4° Jan. 1908.	77·2° July 1905.			65·4°
Minimum day and night Temperatures - -	Aug. 1901 to Oct. 1908.	16·3° Feb. 1902.	66·6° Aug. 1904.	31·5° Feb. 1902.	58·5° July 1905.			50·3°
Depth of sewage at manhole (inches) - - -	Aug. 1901 to Aug. 1906.	8·5″ to Oct. 1904.	36·0″ Oct. 1904.	13·5″ Feb. 1905.	20·9″ Jan. 1906.	14·7″ Oct. 1904.	23·2″ Aug. 1906.	
Rainfall (inches) - - - - - - -	Years 1902–7, inclusive.	17·80″ to 1904.	32·97″ 1903.	Average for the six years, 22·11″.				

SUMMARY.

1. The works are about one mile from the centre of the town, the nearest houses on the sewerage system being about 350 yards distant, and the furthest about four miles.

2. The distance between the large manhole and the entrance to the septic tank is 71 feet; 11 feet of this consist of a narrow open channel, along which the sewage flows in a very thin layer.

3. As was to be expected, there was little difference in temperature between the sewage in the manhole and the sewage as it entered the tank. The average temperature of the former was about 1° F. lower in cold weather and about 1° to 2° F. higher in warm weather than that of the latter. The extremes of temperature were rather less marked in the sewage at the manhole.

4. The average temperature of the septic liquor leaving the tank was a little less than that of the sewage entering it; it was, however, only lower in the morning and not in the afternoon.

5. The distance between the outlet of the septic tank and the filters is about 700 feet (*cf.* p. 229). Since temperatures were only taken for eleven months of the liquor as going on to the filters and of the effluents from the filters, it is necessary, for a proper comparison with the liquor as leaving the tank, to consider the latter in this connection for those eleven months only. We then find that:—

(*a*) The average temperature of the liquor going on to the deep and shallow filters was hardly any less than that of the liquor leaving the tank;

(*b*) The average reduction in temperature of the liquor in its passage through the deep filter was about 0·6°, and in its passage through the shallow filter about 1·8° F.;

(*c*) The extreme average temperatures show a greater difference in the case of the shallow than of the deep filter effluent, and a greater difference in the case of the deep filter effluent than of the liquor passing on to the filter.

6. While the maximum variation in air temperature, between August, 1901 and October, 1908, amounted to 71° F., the maximum variations in the sewage and effluents for the times of observation were only 18·1° and 27·0° F. (This is not a perfectly accurate comparison, since the times covered by the observations are not the same; it is, however, sufficiently near for practical purposes.)

QUANTITATIVE EXPERIMENTS UPON SLUDGE DIGESTION IN SEPTIC TANKS AT ILFORD AND EXETER, BY DR. G. McGOWAN, DR. A. C. HOUSTON, MR. COLIN C. FRYE, AND MR. G. B. KERSHAW.

After working for two years in each case, the septic tank at the Belleisle Sewage Works, Exeter, and the experimental septic tank at Ilford were sludged, and the residual sludges were measured and examined, the sampling being done with the greatest possible care. In both tanks the "flow through" during this period was at the rate of once in 24 hours, approximately.

During these two years,* samples of sewage and of septic tank liquor were drawn, *according to rate of flow of the sewage*, in 24 hourly fractions over one day in every 15 days, the sampling being thus distributed over the different days of the week. As some 40 to 50 such samples of sewage and the same number of samples of tank liquor were drawn at each place, the mean figures obtained from these may reasonably be taken as representing a fair average of the whole flow. The flow was gauged at Exeter on 46 days out of a total of 727, and at Ilford on 394 days out of a total of 730.

At both places the sewages are domestic in character, the Ilford sewage being of about average strength, and that at Belleisle about two thirds as strong. The grit-settlement at Ilford is much the better. The following average figures give an idea of the composition of the four liquors (the figures in brackets indicating the number of estimations in each case):—

Parts per 100,000.

——	Exeter (Belleisle).		Ilford.	
	Sewage.	Septic tank liquor.	Sewage.	Septic tank liquor.
Total Nitrogen - - - - - - -	4·47 (47)	4·17 (42)	7·78 (42)	7·56 (42)
"Oxygen absorbed" from $\frac{N}{8}$ permanganate				
at 27° C. (80° F.) at once - - - -	1·62 (36)	1·12 (36)	2·87 (35)	2·78 (35)
at 27° C. (80° F.) in 4 hours - - - -	6·67 (43)	3·88 (43)	10·09 (43)	7·73 (43)
Solids in suspension - - - - - -	24·74 (46)	9·47 (46)	27·33 (45)	10·89 (45)
Volatile matter in those solids - - - -	15·63 (46)	5·60 (46)	19·62 (45)	8·10 (45)

The average figures for ammoniacal and total nitrogen in corresponding samples, in which the ammonia was estimated, were:—

	Exeter (Belleisle).		Ilford.	
	Sewage.	Septic tank liquor.	Sewage.	Septic tank liquor.
Ammoniacal Nitrogen - - - - -	3·06 (20)	3·50 (20)	5·85 (15)	6·27 (15)
Total Nitrogen - - - - - - -	4·77 (20)	4·54 (20)	7·78 (15)	7·46 (15)
Ratio of Ammoniacal to Total Nitrogen -	1:1·56	1:1·30	1:1·33	1:1·19

The average figures and ratios for suspended solids and solids by centrifuge (volumes) in corresponding samples were:—

——	Exeter (Belleisle).		Ilford.	
	Sewage.	Septic tank liquor.	Sewage.	Septic tank liquor.
Solids in suspension - - - - - -	25·0 (43)	9·6 (43)	27·2 (43)	10·8 (43)
Solids by centrifuge (vols.) - - - -	148·9 (43)	43·4 (43)	242·6 (43)	75·9 (43)
Average ratio of solids in suspension to centrifuge solids - - - - - -	1 : 5·9	1 : 4·5	1 : 8·9	1 : 7·0

*At Exeter, August 22nd, 1904—June 26th, 1906; at Ilford, November 2nd, 1904—August 30th, 1906.

Many of the weaker samples from Exeter, both of sewage and septic tank liquor, contained a very considerable proportion of their nitrogen in the form of nitrate.

The Digestion results obtained may be briefly summarised as follows :—

———	Exeter (Belleisle).		Ilford.	
Length of time that the tank ran	727 days.		730 days.	
Number of days on which the flow was gauged	46		394	
Average daily flow of sewage through tank	70,500 gallons.		19,460 gallons.	
Volume of Residual wet sludge	5,277·2 cubic feet.		1,267·7 cubic feet.	
Specific gravity of wet sludge at about 15° C. (water at 4° C. (39° F.)=1)	1·0727		1·0720	
Percentage of dry matter in sludge	13·57		13·89	
Containing non-volatile matter	9·11		7·66	
Digestion.				
Suspended solids in sewage (dry)	—	126,801 lbs.	—	38,824 lbs.
Dry solids of tank sludge	47,842 lbs.	—	11,756 lbs.	—
Solids escaping in tank liquor	48,537 lbs.	96,379 lbs.	15,470 lbs.	27,226 lbs.
Solids digested	—	30,422 lbs.	—	11,598 lbs.
Percentage of solids digested (with no correction for colloids)	24·0		29·9	

The above specific gravity determinations (as well as the determinations of dry matter) were made from bottles A.A. in the case of both sludges, *i.e.*, from what were considered the best samples. The bottles were kept in ice, and the determination was made between two and three weeks after sampling in the case of the Exeter sludge, and one week after sampling in the case of the Ilford sludge. With the Exeter sludge it was done by direct weighing of a given volume, and with the Ilford sludge by indirect weighing with water, after getting rid of gas bubbles. The latter is probably the better method, though each has its advantages. Other determinations, both direct and indirect, were made with the samples from bottles B.B. and C.C., the results of which did not differ much from those just given. They enable us to say that an indirect determination would not have affected appreciably the Exeter figure for digestion (24 per cent.), while a direct determination would probably have given for Ilford a digestion figure of 30·3, instead of 29·9 per cent.

The figures for Cellulose in samples A.A. were :—

	Exeter (Belleisle).	Ilford.
"Cellulose" (by alkali, acid and ether)	1·50 per cent.	1·97 per cent.
"Cellulose" (by alkali, acid and ether, with previous permanganate treatment)	0·52 per cent.	0·61 per cent.

The corresponding figures from samples B.B. and C.C. were not materially different from these.

In both cases the sludges appeared to be well digested (*cf.* pp. 239 and 251), that from Exeter being more gritty and less glutinous than that from Ilford. It is of course not advisable to look upon figures for digestion of sludge as strictly accurate, but in the above experiments precautions were taken to guard against possible errors, and we think that the foregoing figures may safely be accepted as correct to within about 5 per cent. (*e.g.* for 24 per cent. read 22 to 26 per cent., and for 30 per cent. read 28 to 32 per cent.)

The figures do not take account of the colloidal, or at least of all the colloidal, matter present in the sewages and tank liquors, and an attempt was therefore made to estimate the colloidal (or additional colloidal) matter* in five samples each of the Ilford sewage and tank liquor and in one sample each of those from Exeter. The estimation is a troublesome one, and we require further data on the subject, but the average figures obtained from the ten Ilford samples may be given :—

Parts per 100,000.	Sewage.	Tank liquor.
Colloidal (or additional colloidal) matter	2·2 (5)	3·5 (5)
Ordinary suspended solids, as estimated on a Gooch crucible	27·3 (45)	10·9 (45)

There thus appears to have been about 1 part per 100,000 more of colloidal matter in the tank liquor than in the sewage. Applying, tentatively, the corrections for colloids to the above results, we get the digestion for total (including colloidal) solids in the case of Ilford to be 23 per cent. The Exeter liquors probably contained rather less colloidal matter, but a roughly proportional correction would bring down the digestion of the total (including colloidal) solids to about 20 per cent.

An interesting ratio in the figures of analysis comes out in both cases, which can be best explained by giving the figures themselves :—

Parts per 100,000.	Exeter (Belleisle).	Ilford.
(A) Suspended solids of sewage, volatile on ignition	15·63	19·62
Minus suspended solids of septic tank liquor, volatile on ignition	5·60	8·10
Difference	10·03	11·52
(B) Percentage figure obtained for digestion (leaving colloids out of account)	24·0	29·9
Ratio of (A) to (B)	1 : 2·4	1 : 2·6

* This estimation was made indirectly by filtering (*a*) one portion of the sewage liquor through asbestos in a Gooch crucible, and (*b*) another portion through a fine-grained earthenware candle, with precautions against evaporation of either filtrate. Equal volumes of the two filtrates were then evaporated in small basins, which were dried in the same oven at about 105° C. until the weights were constant, or practically so, each pair of basins being weighed together, *i.e.*, the one basin immediately after the other.

This ratio, if sufficiently corroborated at other places, might be useful as indicating the degree of digestion which a domestic sewage might be expected to undergo in a septic tank. The same idea as regards a ratio had already occurred to Mr. W. H. Harrison, when engaged at the Leeds sewage works, and a ratio had been applied by him.

ANALYSIS OF THE EXETER (BELLEISLE) SEPTIC TANK SLUDGE.

In the Ilford report (this Appendix, p. 238), the analysis is given of the sludge taken from the experimental tank there in September, 1906. It is therefore only necessary to give the analysis of the Exeter sludge here.

The sampling of the Exeter sludge extended over eight days, from July 19th—26th, 1906. A mixture was made of 241 samples, each one taken from a measured tumbler cart, and each in proportion to the content of the tumbler. From this mixture, bottles A, B, and C were filled. On reaching the laboratory the bottles were put in ice. Bottle A was regarded as the best sample of the three, and bottle C as the worst.

	Bottle A. (from middle of mixing vessel).			Bottle B. (from top of mixing vessel).		Bottle C. (from bottom of mixing vessel).	
Analysis begun - - - -	July 27th, 1906.			July 27th.		July 27th.	
	a	*b*	*c*	*a*	*b*	*a*	*b*
Total Nitrogen * (by Kjeldahl)	304·2	316·5	315·4	294·3	337·7	313·5	344·3
Mean - - - - -		312·0		316·0		328·9	
"Oxygen absorbed" from $\frac{N}{8}$ permanganate at 27° C.:—							
at once - - - -	414·1	397·6		412·5	395·3	368·6	350·0
Mean - - - -		405·9		403·9		359·3	
"Oxygen absorbed" at 27° C. *in 4 hours* - - - - - -	1956·2	1821·0		1855·8	1772·7	1516·4	1789·1
Mean - - - - -		1888·6		1814·3		1652·8	
Dissolved Oxygen taken up from water at 18° C.† - - -	In 3 days. 413·2			In 3 days. 405·9		In 3 days. 419·1	
Volumes of tap water added for 1 grm. of sludge - - -	4,245			4,092		3,624	

The percentage of dry matter was almost the same in both of these sludges from Ilford and Exeter, but the Exeter sludge contained less nitrogenous and carbonaceous matter, and therefore presumably more grit.

Gas Evolution Experiment; begun July 27th, 1906.

11·7653 grm. of the wet sludge from (Exeter) bottle A, containing 13·57 per cent. of dry matter, were placed in a bottle of 378 c.c. capacity, that of the evolution tube being 5 c.c. The bottle and tube were then filled up with distilled water containing 5·9 c.c. oxygen per litre, and the gas evolved was collected in fractions, as before. The following fractions were measured (reduced to 0° C. and 760 m.m Mercury pressure):—

Gas evolved between July 27th and August 11th, 1906 - - - - - - -	20·1 c.c.
Gas evolved between August 11th and October 9th, 1906 - - - - - - -	23·2‡c.c.
Gas evolved between October 9th, 1906, and September 29th, 1909 - - - - -	20·1 c.c.
Gas remaining in evolution tube, say - -	0·3 c.c.
Total gas from 11.7653 grm. wet sludge - -	63·6 c.c.

(making no correction for the dissolved oxygen in the water taken).

The volume of gas given off under the above conditions of experiment was thus about 40 per cent. greater than in the case of the Ilford sludge, so far as can be judged from the small samples taken. Still, the above volume of gas is not very large, the sludge having evidently been fairly well digested in the tank.

The following table summarizes shortly the gas evolution results from both sludges:—

——	Weight of wet sludge taken (grms).	Capacity of water bottle and evolution tube. (c.c.).	Oxygen in solution in the water used (c.c.)	Total gas evolved, reduced to N.T.P. (c.c.).
Ilford - - - - - - - - -	16·658	386	2·33	64·0
Exeter - - - - - - - - -	11·765	383	2·25	63·6

We would desire to express our thanks to Mr. Golding, City Engineer at Exeter, and Mr. Marden, Manager of the Sewage Works; also to Mr. Shaw, City Engineer at Ilford and Mr. H. Chittock, Manager of the Sewage Works, for their help in connection with the foregoing work. Mr. Marsden and Mr. Chittock were responsible for the regular sampling of the sewage and septic tank liquor throughout the two years in question.

GEORGE McGOWAN.
A. C. HOUSTON.
COLIN C. FRYE.
G. B. KERSHAW.

December, 1909.

* For the estimation of the nitrogen and of the "oxygen absorbed" from permanganate, a weighed quantity of sludge (about 12 grms.) was made up to 1,000 c.c. with distilled water; the mixture would have been better had the sludge been ground up with the water. From this mixture the following quantities were taken:

For Nitrogen (by Kjeldahl) - - - - - - - - - - -	100 c.c.
For "Oxygen absorbed" at once - - - - - - - - -	25 c.c.
For "Oxygen absorbed" in 4 hours - - - - - - - - -	10 c.c.

† The dissolved oxygen used up varied from 13 to 15 per cent. of the total present.

‡ It is just possible, but improbable, that a little gas may have been lost here.

PRELIMINARY LABORATORY EXPERIMENTS ON THE BIOLOGICAL PURIFICATION OF SEWAGE. BY DR. A. C. HOUSTON.

DESCRIPTION OF APPARATUS.

The apparatus used in the experiments is shown in figure 1 (diagrammatic).

The large vessel (I) contained the liquid to be treated. When the stopcock was very slightly opened the liquid dropped into the funnel and gradually filled the bottle (H). After a certain interval the liquid siphoned over into the bottle (G) and escaping therefrom was split into two streams by the Y tube, the two arms (J. and K.) of which were fitted with fine nozzles, and allowed approximately equal volumes of the liquid to spurt into separate funnels. One funnel was connected with bottle (E) which was maintained at such a temperature as to kill the bacteria present in the liquid, other than those present in the form of spores. The other funnel was connected with a similar bottle (F) which was not heated. The liquid from bottle (E) escaped from time to time into the bottle (C). The bottle (C) was surrounded with cold water, for cooling purposes, contained in a suitable vessel which (although this is not shown in the diagram) also contained the bottle (D). The liquid from bottle (C) siphoned over, along the tube (N) into an open vessel (Y). Similarly, the liquid from the bottle (D) siphoned over, along the tube (M) into another open vessel (Z). From the vessel (Y) the liquid siphoned over into the perforated tray lid of the filter (A). The perforations were covered over with a layer of small bits of coke. In the same way the liquid from the vessel (Z) siphoned over into the perforated tray lid of the filter (B). Here also there was a layer of coke. The temperature of the liquid reaching the filters was about the same in each case. The liquid when it siphoned over into the perforated tray lids of the filters (A and B) spread over the surface, and escaping slowly through the small perforations was thus distributed over the surface of the coke. The filters gradually filled and eventually the liquid siphoned over. The coke (passing ¾″ but rejected by ½″ mesh) was, in each filter, supported on a perforated false bottom. The coke had not been used previously for sewage purification purposes. Filter A., when empty, had a siphon capacity of 3,667 c.c. When filled with coke the liquid capacity was 1,925. Filter B. when empty had a siphon capacity of 3,610 c.c. and when filled with coke the liquid capacity was reduced to 1,790 c.c.

The experiments being on a very small scale presented many practical difficulties. But, of course, the object of the experiments was not to achieve a maximum degree of purification, but to try to throw some light on the nature of some of the biological processes which bring about the purification of sewage. It was hoped subsequently to carry out experiments on a much larger scale and under improved conditions, but this has not been found practicable.

OBJECTS OF THE EXPERIMENTS.

It is very difficult to describe the precise objects of the experiments about to be detailed. In carrying out research work one is sometimes led to carry out experiments, and to vary them, without much more than a sub-conscious hope that the results may, in one way or another, yield a little fresh knowledge, or help, directly or indirectly, to throw some new light on previously ascertained facts. At all events, I can lay no claim to having started the experiments with a "cut and dried" programme of procedure, or with fully crystallised ideas of the exact way in which the initial experiments were likely to develop, or even with a clear conception of their precise bearing on the many problems associated with the purification of sewage. Incidentally, in carrying out the experiments, I have reached certain provisional conclusions which may be of some little interest. Nevertheless, I trust that the unpretentious character of the experiments and the tentative nature of the conclusions will be borne in mind.

In the first series of experiments it was sought to compare (chemically and bacteriologically) the effluent from two similar (initially sterile) filters, the one (filter B) receiving "unheated sewage," and the other (filter A) sewage previously heated, so as to kill all microbes other than those present in the form of spores.

In the second series of experiments the treatment was reversed, with the idea of comparing (chemically and bacteriologically) the effluent from a filter (filter B) "matured" in the ordinary way to start with, and then treated with sewage in which all the bacilli (but not their spores) had been killed, with the effluent from a filter (filter A) falsely (as it were) "matured" with sporing bacteria to start with, and then treated with sewage unaltered by heating.

In the third series of experiments the object was to see the kind of chemical and bacteriological effluent yielded by a *now* mature filter (filter A), when instead of being treated with sewage, it was dosed with *sterile* sodium chloride solution. As regards B filter, no alteration was made at this stage.

In the fourth series of experiments it was sought to determine the chemical and bacteriological qualities of the A filter effluent when, after prolonged treatment with *sterile* sodium chloride solution, a return was made to normal treatment with sewage. As regards B filter, no alteration was made at this stage.

In the fifth series of experiments the tests were directed towards finding out the effect on the B filter effluent of changing the dose from sewage previously heated to 80°C. to sewage *completely* sterilised by means of heat. As regards A filter, the conditions remained the same as in the fourth series of experiments.

In the sixth series of experiments it was sought to discover the effect on the effluent from A filter (now again matured) of changing the dose from sewage to dilute sterile (by Pasteur filtration) urine. As regards B filter, no alteration was made at this stage.

In the seventh series of experiments the object was to note the result of treating the A filter with a sterile "urea mixture" in place of dilute urine. The B filter still continued to treat sterilised sewage.

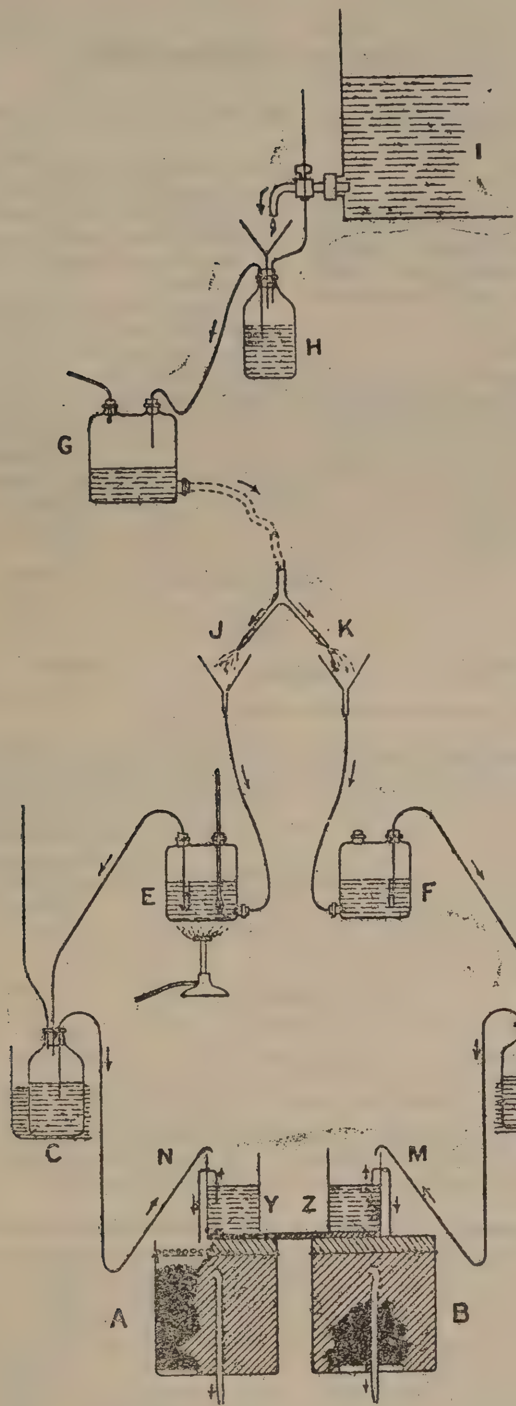

FIGURE 1.

The Commission will remember that Mr. Colin Frye carried out a series of experiments at Leeds in which he showed that, although a mature filter could not appreciably oxidise sewage sterilised with corrosive sublimate, it could oxidise steam sterilised sewage. Further, that a sterile filter could not appreciably oxidise sterile sewage. Later, Dr. McGowan showed that a mature filter could oxidise pot ale (previously diluted with water and neutralised with lime).* Allusion should also be made to experiments carried out, at the suggestion of the Commission, by Mr. Harrison at Leeds, in which he dosed a mature sewage filter with potable water for some time. The effluent resembled one resulting from the treatment of a highly dilute sewage.

I have to acknowledge the valuable assistance of Miss Power and Miss Hartley throughout the whole course of the investigation. During the later stages of the experiments, I had also the great advantage of the help and advice of Dr. Harriette Chick, who has carried out many instructive investigations on the nitrification of sewage. Since this report was written some important work by Dr. Gilbert Fowler and Mr. Percy Gaunt on "The Interaction of Dilute Solutions of Ammonium Salts and various Fitering Media" has been published (July 15th, 1907. "Journal of the Society of Chemical Industry," No. 13, Vol. XXVI.)

* In connection with the subject of disposal of distillery refuse, reference should be made to an important paper by Mr. James Hendrick, B.Sc., F.I.C., dated May 31st, 1901, on "The Composition and Disposal of Burnt Ale and other Waste Liquids of Whisky Distilleries."

1st SERIES OF EXPERIMENTS.

1st Series of Experiments. A filter treats "heated" Sewage; B filter treats "unheated" Sewage.

A Filter treats "heated" Sewage; B Filter treats "unheated" Sewage.

January 18th, 1903.

The experiments were started on January 18th, 1903, by sterilising the whole apparatus (with the coke *in situ*) by passing through it first a strong solution of copper sulphate, then a weak solution of acid, next a weak alkaline solution, then a strong solution of formalin, and finally sterile water.

January 19th, 1903.

The liquid to be treated (contained in bottle I.) consisted of equal parts of paper-filtered Hendon crude sewage and tap water. The liquid was started dropping continuously from the large vessel (I) on the evening of January 18th. It is important to note that the flow (dropping) was continuous and as far as possible uniform in rate, because at a later date the method of treatment was altered.

Between January 19th and February 1st, Filter A had received 18, and Filter B 21 fillings.

On February 1st, a bacteriological analysis of the liquid being treated, and the effluent from A and B filters was made. The results were as follows :—*

—	Dilute Sewage. Per c.c.	Effluent from A filter (treating sewage previously *heated*) † Per c.c.	Effluent from B filter (treating sewage *not* previously heated). Per c.c.
B. coli test - - - - - - -	100,000 (typical)	None	10 (typical)
B. enteritidis sporogenes test - - - -	100	1	1
Total number of microbes (agar at 37° C.) -	2,300,000	488,000	6,100

It will be noted that although the effluent from the A filter contained many more microbes than the B filter effluent B coli was absent from 1 c.c. of the former.

By the morning of February 6th, filters A and B had received 24 and 27 fillings respectively. The resulting effluents were examined chemically and bacteriologically.

—	Dilute Sewage. Per c.c.	Effluent from A filter (treating sewage previously *heated*). Per c.c.	Effluent from B filter (treating sewage *not* previously heated). Per c.c.
B. coli test - - - - - - -	100,000 (typical)	None	1,000 (typical)
B. enteritidis sporogenes test - - - -	100	1	10
Total number of microbes (agar at 37° C.) -	2,400,000	1,490,000	123,000

Here also the effluent from A filter contained a far larger number of microbes than the effluent from B filter. But whilst the former contained no B. coli per c.c., the latter contained 1,000.

As regards the chemical results, these are incorporated in the following table :—

Oxygen absorbed from permanganate of potassium, 4 hours at laboratory temperature. Parts per 100,000.
(The standard solution used contained 0·395 grammes $K.Mn.O_4$ in one litre).

—	Dilute Sewage.	Effluent from A filter (treating sewage previously *heated*).	Effluent from B filter (treating sewage *not* previously heated).
February 6th - - - - - - -	1·50	·43* (24 fillings)	·53‡ (27 fillings)
" 7th - - - - - - -	·91	·7* (26 fillings)	·59* (28 fillings)
" 7th - - - - - - -	·84	·66 (27 fillings)	·5 (29 fillings)
" 8th - - - - - - -	·82	·48 (28 fillings)	·36 (30 fillings)
" 9th - - - - - - -	1·34	·4 (30 fillings)	·28 (32 fillings)
Averages - - - - - -	**1·082**	**0·534** 50 per cent. purification.	**0·452** 58 per cent. purification.

* Three stoppered bottles (a, b, c,) were completely filled with (a) the liquid being treated, (b) effluent from filter A, and (c) effluent from filter B. To each was added a trace of tartrate of iron. The bottles were incubated at 30° C. for one month. The contents of (a) became black, but in the case of (b) and (c) no blackening occurred.

† Throughout this report the word "heated" implies the destruction of all microbes (other than those present in the form of spores) by heating the liquid to 80° C. for over ten minutes. This treatment, of course, would kill B. coli, B. proteus, etc. As the heating operation was *subsequent* to the mixing of the tap water with the sewage it will be understood that *both* the tap water and sewage were heated (*see* Fig. 1 and description of apparatus).

‡ These samples were tested for nitrites and yielded negative results.

The actual results were thus not good and the percentage degree of purification unsatisfactory; the effluent from filter B was somewhat better than the effluent from filter A.

1st Series of Experiments. A filter treats "heated" Sewage; B filter treats "unheated" Sewage.

On February 10th, the liquid being treated and the effluents from A filter (31st filling), and B (34th filling), were examined bacteriologically with the following results:—

——	Dilute Sewage. Per c.c.	Effluent from A filter (treating sewage previously *heated*). Per c.c.	Effluent from B filter (treating sewage *not* previously heated). Per c.c.
B. coli test - - - - -	10,000 (typical)	None	100 (typical)
B. enteritidis sporogenes test -	10	1	10
Total number of microbes (agar at 37° C.) - - - - -	1,200,000	900,000	56,000

It will be noted that again the effluent from the A filter contained no B. coli, but a large number of microbes, whereas the effluent from the B filter contained 100 B. coli, but a smaller number of microbes.

On February 11th, the liquid being treated and the effluents from A filter (32nd filling) and B (36th filling) were examined chemically and bacteriologically. The bacteriological results were as follows:—

——	Dilute Sewage. Per c.c.	Effluent from A filter (treating sewage previously *heated*). Per c.c.	Effluent from B filter (treating sewage *not* previously heated). Per c.c.
B. coli test - - - - -	10,000 (typical)	None	1,000 (typical)
B. enteritidis sporogenes test -	100	None	1
Total number of microbes (agar at 37° C.) - - - - -	2,300,000	260,000	57,000

As before the effluent from A filter, although it contained no B. coli, contained a much larger number of microbes than the effluent from the B filter.

The chemical results are given in the following table:—

Oxygen absorbed from permanganate of potassium, 4 hours at laboratory temperature. Parts per 100,000.

——	Dilute Sewage.	Effluent from A filter (treating sewage previously *heated*).	Effluent from B filter (treating sewage *not* previously heated).
February 11th - - - -	1·48	·38 (32 fillings)	·378 (36 fillings)
" 12th - - - -	1·56	·46 * (34 fillings)	·48 * (38 fillings)
" 13th - - - -	1·36	·48 * (36 fillings)	·44 * (40 fillings)
" 14th - - - -	1·28	·54 * † (37 fillings)	·48 * † (42 fillings)
" 15th - - - -	1·04	·51 * (38 fillings)	·468 * (43 fillings)
Averages - - - -	**1·34**	**·47** 64 per cent. purification.	**·45** 66 per cent. purification.

It may be noted at this stage that the purification, although not great, was about the same for both effluents and that nitrification had apparently not set in in either case.

On February 16th the liquid being treated and the effluents from A and B filters (40 and 45 fillings respectively) were examined chemically and bacteriologically. The bacteriological results were as follows:—

——	Dilute Sewage. Per c.c.	Effluent from A filter (treating sewage previously *heated*). Per c.c.	Effluent from B filter (treating sewage *not* previously heated). Per c.c.
B. coli test - - - - -	100,000 (typical)	1 (typical)	1,000 (typical)
B. enteritidis sporogenes test -	100	1	10
Total number of microbes (agar at 37° C.) - - - -	1,200,000	940,000	12,000
Urea fermenting microbes -	1,000	10	100
Nitroso-bacteria (nitrite producing bacteria) - - - - -	10	10	100

In this instance a few B. coli appeared to have escaped destruction in connexion with the A filter process of treatment. Broadly, however, the results, as previously, showed that the A filter contained many microbes but almost no B. coli, whereas the B filter effluent contained a much smaller number of bacteria and contained also B. coli in abundance.

* Effluents tested (with meta-phenylene-diamine) for nitrites with negative results. † Effluents tested for nitrates (phenol-sulphonic method) with negative results.

1st Series of Experiments, A filter treats "heated" Sewage; B filter treats "unheated" Sewage.

As regards the chemical results these are incorporated in the following table :—

Oxygen absorbed from permanganate of potassium, 4 hours at laboratory temperature. Parts per 100,000.

——	Dilute Sewage.	Effluent from A filter (treating sewage previously *heated*).	Effluent from B filter (treating sewage *not* previously heated).
February 16th - - -	·916	·52 (40 fillings)	·46 (45 fillings)
„ 17th - - -	1·356	·58 * (41 fillings)	·44 * (47 fillings)
„ 18th - - -	1·520	·50 (42 fillings)	·42 (48 fillings)
„ 19th - - -	1·184	·64 (44 fillings)	·50 (49 fillings)
„ 20th - - -	1·200	·60 * (45 fillings)	·54 * (50 fillings)
„ 21st - - -	1·080	·56 (46 fillings)	·46 † (51 fillings)
Averages - -	**1·209**	**·567** 53 per cent. purification.	**·470** 61 per cent. purification.

It will be noted that, as judged by the permanganate test, the purification effected was not great but was nearly the same in each case.

On the afternoon of February 21st the liquid to be treated (i.e., in bottle I.) was increased in strength to 2 parts of filtered sewage and 1 part of water (2 in 3 instead of, as previously, equal parts).

On February 22nd, 23rd and 24th the following results were obtained :—

Oxygen absorbed from permanganate of potassium, 4 hours at laboratory temperature. Parts per 100,000.

——	Dilute Sewage.	Effluent from A filter (treating sewage previously *heated*).	Effluent from B filter (treating sewage *not* previously heated).
February 22nd - - -	1·52	·66 (48 fillings)	·64 (53 fillings)
„ 23rd - - -	1·36	·71 (50 fillings)	·704 (54 fillings)
„ 24th - - -	1·036	·70 (52 fillings)	·616 (55 fillings)
Averages - -	**1·305**	**·69** 47 per cent. purification.	**·653** 50 per cent. purification.

On the afternoon of February 24th unfiltered and undiluted but settled sewage was used in bottle I. for the first time.

On February 25th, 26th, 27th and 28th the following results were obtained :—

Oxygen absorbed from permanganate of potassium, 4 hours at laboratory temperature. Parts per 100,000.

——	Sewage.	Effluent from A filter (treating sewage previously *heated*).	Effluent from B filter (treating sewage *not* previously heated).
February 25th - - -	4·20	1·26 (54 fillings)	1·44 (57 fillings)
„ 26th - - -	4·36	1·76 (55 fillings)	1·84 (58 fillings)
„ 27th - - -	4·49	1·48 (56 fillings)	1·94 (59 fillings)
„ 28th - - -	2·80	2·00 (57 fillings)	1·72 (60 fillings)
Averages - -	**3·96**	**1.62** 59 per cent. purification.	**1·73** 56 per cent. purification.

At this stage the actual results were so unsatisfactory that after A filter had dealt with its 58th filling and B filter with its 61st filling the experiment was stopped temporarily. The filters showed signs of "sickening" and had an unpleasant sour smell. Moreover, some of the connections of the apparatus showed signs of blocking. Up to this stage the filters had been lightly covered over with cloths to keep out the dust. The cloths were

* Tested for nitrites with negative results. † Tested for nitrates with negative results.

removed and other minor alterations made, but before describing these it will not be amiss to epitomise very briefly the results obtained up to this point.

SUMMARY AT THIS STAGE.

Bacteriological Results.—It will be remembered that the liquid going to A filter to be treated was subjected to a preliminary process of heating. Although the heating arrangements were not altogether satisfactory the main object was attained, namely, to kill all bacteria not present in the spore form. Broadly, the liquid was subjected for over 10 minutes to a temperature which never fell as low as 65° C. and never rose above 80° C. It is possible, however, that sometimes the liquid may have been slightly over-heated or even under-heated.

B. coli Results.—The liquid being treated contained from 10,000 to 100,000, the effluent from B filter from 10 to 1,000, and the effluent from A filter no B. coli.*

Total Number of Microbes.—The average number of bacteria in the liquid being treated, the effluent from A filter, and the effluent from B filter was 1,880,000; 815,600 (56 % reduction); 50,820 (97 % reduction).

It is apparent that the effluent from the A filter contained many more microbes than the effluent from the B filter, despite the fact that in the case of the former the non-sporing bacteria (*e.g.*, B. coli, B. proteus, etc.) in the liquid being treated were destroyed by the preliminary heating process.

Chemical Results.—The results were striking inasmuch as the percentage purification effected by the two filters was very similar, notwithstanding that in the one case (A filter) the microbes (*e.g.*, B. coli, B. proteus, etc.) commonly thought of as associated with the process of purification had been destroyed by heat. The degree of purification effected, however, was unsatisfactory, and no oxidised nitrogen was present in either effluent.

1st Series of Experiments. A filter treats "heated" Sewage; B filter treats "unheated" Sewage.

The average figures were as follows:—

Oxygen absorbed from permanganate (4 hours at laboratory temperature). Parts per 100,000. Average of 23 samples.

Liquid being treated.	Effluent from A filter.	Effluent from B filter.
1·702	·74 (56% purification.)	·705 (58% purification.)

The tentative inference arising from a consideration of the foregoing results is that the sporing bacteria in sewage are capable themselves of effecting some measure of purification (so far as oxidation of the carbonaceous matter is concerned) of sewage, and that the presence of such non-sporing bacteria as B. coli, B. proteus, etc., is not *essential* to the purification process. It is here assumed, however, without, perhaps, sufficient warrant, that filter A owed none of its purifying ability to microbes accidentally entering the filter from outside (*e.g.*, from air or dust).

On March 1st the heating vessel E was removed and a more efficient apparatus substituted. (*See* Figure 2.) Further, the rate of flow was greatly increased and long periods of rest allowed. Previously the flow was excessively slow but continuous.

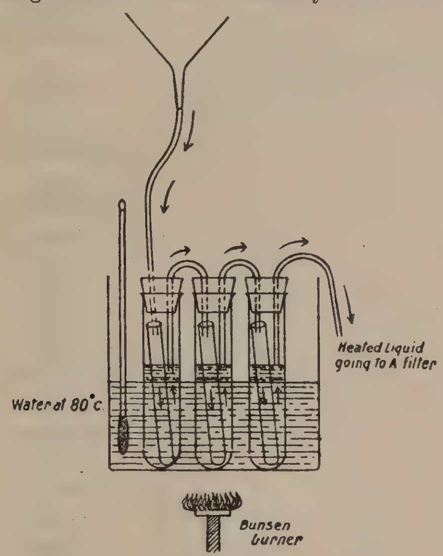

FIGURE 2.

The chemical results during the next few days may be given in a table as follows:—

Oxygen absorbed from permanganate, 4 hours at laboratory temperature. Parts per 100,000.

———	Liquid being treated (settled sewage).	Effluent from A filter (treating sewage previously *heated*).	Effluent from B filter (treating sewage *not* previously heated).
March 2nd	1·77	1·8 (59 fillings)	1·668 (62 fillings)
" 3rd	2·2	1·56 (60 fillings)	1·6 (63 fillings)
" 4th	2·35	1·2 (61 fillings)	1·24 (64 fillings)
" 5th	3·29	1·0 (62 fillings)	1·20 (65 fillings)
" 6th	3·4	1·04 (63 fillings)	1·2 (66 fillings)
" 7th	2·8	1·04†‡ (64 fillings)	1·12†‡ (67 fillings)
" 9th	3·0	1·16 (65 fillings)	1·32 (68 fillings)
Averages	**2·68**	**1·25** (53% purification)	**1·335** (50% purification)

* In one instance the effluent from A filter did contain B. coli in 1 c.c., but not in $\frac{1}{10}$ c.c., owing, no doubt, to a temporary inefficiency of the heating apparatus.

† Effluents tested for nitrites with negative results. ‡ Effluents tested for nitrates with negative results.

1st Series of Experiments. A filter treats "heated" Sewage; B filter treats "unheated" Sewage.

On 6th, 7th and 9th of March the effluent from A filter was tested bacteriologically. No B. coli were found in 1 c.c.

The chemical results still remaining unsatisfactory, the rate of flow was greatly diminished, and shorter periods of rest given between each contact. As time went on, however, the rates of flow and periods of rest were constantly varied in the hope of improving the purification. It appears unnecessary to describe in detail these variations, and it will suffice to give tables illustrating the chemical and bacteriological results, with notes, as regards dates and number of fillings.

Oxygen absorbed from permangana'e of potassium, 4 hours at laboratory temperature. Parts per 100,000.

—	Liquid being treated (settled sewage).	Effluent from A filter (treating sewage previously *heated*).	Effluent from B filter (treating sewage *not* previously heated).
March 10th - - - - -	2·7	1·08 (66 fillings)	1·32 (69 fillings)
" 11th - - - - -	3·1	1·2 (67 fillings)	1·36 (70 fillings)
" 12th - - - - -	3·4	1·36 (68 fillings)	1 56 (71 fillings)
" 13th - - - - -	4·5	1·20 (69 fillings)	1·44 (72 fillings)
" 14th - - - - -	2·5	1·20 (70 fillings)	1·44 (73 fillings)
" 16th - - - - -	3·3	1·2 (71 fillings)	1·52 (74 fillings)
" 17th - - - - -	3·2	1·24 (72 fillings)	1·68 (75 fillings)
" 18th - - - -	3·4	1·44 (73 fillings)	1·68 (76 fillings)
" 19th - - - - -	3·4	1·72 (74 fillings)	1·96 (77 fillings)
" 22nd - - - - -	2·9	1·88 (75 fillings)	2·4 (78 fillings)
" 23rd - - - - -	5·0	2·24 (76 fillings)	2·76 (79 fillings)
" 24th - - - - -	3·0	1·88 (77 fillings)	2·16 (80 fillings)
" 25th - - - - -	3·8	1·60 (78 fillings)	2·4 (81 fillings)
" 26th - - - - -	2·6	1·48 (79 fillings)	2·44 (82 fillings)
" 27th - - - - -	3·8	1·40 (80 fillings)	2·40 (83 fillings
" 28th - - - - -	5·5	1·72 (81 fillings)	2·64 (84 fillings
" 29th - - - - -	5·2	2·08 (82 fillings)	2·88 (85 fillings)
April 3rd - - - - -	3·6	1·80 (84 fillings)	2·48 (87 fillings)
" 4th - - - - -	2·5	1·60 (85 fillings)	2·20 (88 fillings)
" 6th - - - - -	3·7	1·40 (86 fillings)	2·12 (89 fillings)
Averages - - - - -	**3·55**	**1·536** (56 per cent. purification.)	**2·042** (42 per cent. purification.)

On March 22nd, 23rd, 24th, 25th, 26th, 27th, 28th, 29th, and April 3rd, 4th and 6th, the effluents from A and B filters were tested for nitrites. The former (A) gave negative and the latter (B) positive results in each instance.

On March 22nd and 28th, and April 4th and 6th, the effluents were tested for nitrates. A filter yielded negative, and B filter negative on the two former, but positive on the two latter occasions.

Nitrification was thus absent in the case of filter A, but as regards filter B nitrites first appeared in the effluent and later nitrates.

It will be noted that although filter B showed signs of commencing nitrification, the percentage degree of purification as judged by the permanganate test was actually greatest in the case of filter A. In both cases the purification was unsatisfactory.

A number of comparative analyses of previously heated and "unheated" sewage were made, but as judged by the average permanganate figures, there was no indication that the heating altered the sewage to any material extent.

On March 10th, 11th, 12th, 13th, 14th, 16th, 17th, 18th and 19th, the effluent from A filter was tested for the presence of B. coli. No B. coli were present in 1 c.c. of effluent.

On March 28th a more complete bacteriological analysis was made, with results as follows :—

1st Series of Experiments. A filter treats "heated" Sewage; B filter treats "unheated" Sewage.

——	Liquid being treated (settled sewage). Per c.c.	Effluent from A filter (treating sewage previously *heated*). Per c.c.	Effluent from B filter (treating sewage *not* previously heated). Per c.c.
B. coli test	100,000	None.	10,000
B. enteritidis sporogenes test	1,000	10	1,000
Total number of microbes (agar at 37° C.)	19,200,000	1,360,000 (92 per cent. reduction)	92,000 (99 percent. reduction)
Urea fermenting microbes	10,000	? 1	1,000
Nitroso-bacteria (nit*r*ite producing bacteria)	100	None.	10,000

It will be noted that, as before, the effluent from A filter contained many more microbes than the effluent from B filter. But, also as was previously noted, the A filter was purifying the sewage despite the destruction, by heat, of all but the spores of bacteria. Nevertheless, at this stage the B filter only was nitrifying the sewage.

On April 7th the coke was taken out of the tray lids of both filters, the perforations in the trays were cleaned by means of sterile water, and bent pieces of sterile wire were placed in the holes, the idea being to improve the distribution over the coke in the filters.

The filters were then re-started, and the results of the chemical analysis of the effluents during the ensuing fortnight were as follows :—

Oxygen absorbed from permanganate, 4 hours at laboratory temperature. Parts per 100,000.

——	Liquid being treated (settled sewage.)	Effluent from A filter (treating sewage previously *heated*).	Effluent from B filter (treating sewage *not* previously heated).
April 7th	3·1	1·12 (87 fillings)	1·64 (90 fillings)
„ 8th	3·1	·96 (88 fillings)	1·48 (91 fillings)
„ 13th	2·54	·88 (89 fillings)	1·36 (92 fillings)
„ 14th	2·16	1·0 (90 fillings)	1·2 (93 fillings)
„ 15th	2·74	1·16 (91 fillings)	1·4 (94 fillings)
„ 16th	2·49	1·08 (92 fillings)	1·32 (95 fillings)
„ 17th	3·9	1·36 (93 fillings)	1·56 (96 fillings)
„ 18th	2·8	1·0 (94 fillings)	1·2 (97 fillings)
„ 20th	5·0	1·24 (95 fillings)	1·48 (98 fillings)
Averages	**3·09**	**1·09** (64 % purification)	**1·4** (54 % purification)

As regards nit*r*ites, all the effluents from B filter, except the last, yielded positive results, although sometimes only traces were present. All the effluents from A filter gave negative results.

As regards nitr*a*tes all the B filter effluents yielded distinctly positive results, but all the effluents from A filter gave quite negative results.

Two of the sets of the samples were tested for free and albuminoid ammonia,* with results as follows :—

Parts per 100,000.

—	Liquid being treated (settled sewage).		Effluent from A filter (treating sewage previously *heated*).		Effluent from B filter (treating sewage *not* previously heated).	
	Free.	Albuminoid.	Free.	Albuminoid.	Free.	Albuminoid.
April 18th	7·72	·64	3·088	·576	4·688	·224
„ 20th	5·74	1·12	5·888	·256	3·888	·416

* The results, throughout the report, are expressed in terms of free and albuminoid *ammonia*, not in terms of free and albuminoid *nitrogen*.

1st Series of Experiments. A filter treats "heated" Sewage; B filter treats "unheated" Sewage.

One set of samples was examined bacteriologically on April 15th, with results as follows:—

—	Liquid being treated (settled sewage). Per c.c.	Effluent from A filter (treating sewage previously *heated*). Per c.c.	Effluent from B filter (treating sewage *not* previously heated). Per c.c.
B. coli test - - - - - -	100,000	None.	1,000
B. enteritidis sporogenes test -	1,000	10	10
Total number of microbes (agar at 37° C.) - - - - - -	960,000	450,000	28,000
Urea fermenting microbes - -	10,000	? 10	10,000
Nitroso-bacteria (nitrite producing bacteria) - - - - - -	100	1	100,000

On April 20th, after A filter had dealt with 95 fillings and B filter with 98 fillings, a temporary modification in the method of working was made.

To the outlet end of each syphon tube a T-piece with stopcock and vertical glass tube was attached (*see* Figure 3). The stopcock was closed, and when the filter syphoned over, the stopcock was opened slightly so as to allow the filter to empty very slowly, instead of as before, very rapidly.

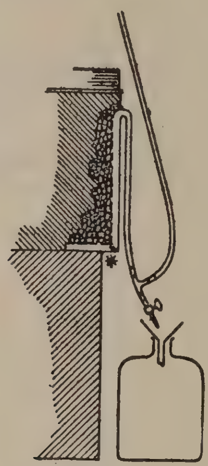

FIGURE 3.

The results between April 20th and May 2nd were as follows:—

Oxygen absorbed from permanganate, 4 hours at laboratory temperature. Parts per 100,000.

—	Liquid being heated (settled sewage).	Effluent from A filter (treating sewage previously *heated*).	Effluent from B filter (treating sewage *not* previously heated).
April 21st - - - - - -	3·9	1·36 (96 fillings)	1·40 (99 fillings)
„ 22nd - - - - - -	5·52	1·68 (97 fillings)	1·44 (100 fillings)
„ 23rd - - - - - -	4·75	2·16 (98 fillings)	2·08 (101 fillings)
„ 24th - - - - - -	4·76	2·16 (99 fillings)	1·88 (102 fillings)
„ 25th - - - - - -	5·73	2·08 (100 fillings)	1·48 (103 fillings)
„ 27th - - - - - -	4·80	2·28 (101 fillings)	1·80 (104 fillings)
„ 28th - - - - - -	6·2	2·08 (102 fillings)	1·44 (105 fillings)
„ 29th - - - - - -	3·7	2·48 (103 fillings)	1·88 (106 fillings)
May 2nd - - - - - -	3·0	2·88 (104 fillings)	1·64 (107 fillings)
Averages - - - - -	**4·7**	**2·13** (54 per cent. purification)	**1·67** (64 per cent. purification)

As regards nitrites, it is important to note that all the samples of A filter effluent now gave a distinctly positive result. This, no doubt, accounts for the higher figures yielded by the permanganate test, as the nitrite would *per se* reduce the permanganate. The effluent from B filter now yielded only traces of nitrite.

In respect of nitrates an opposite result was obtained, A filter yielding practically none, whereas B filter gave results as follows :—

April 21st, 22nd, 23rd, 24th, 25th, 27th, 28th, 29th and May 2nd : 2, 2, 1·9, 2, 2·3, 3·0, 2, 3, and 2·5 parts per 100,000 (average = 2·3).

It will thus be seen that the history of B filter was in no way peculiar, except that nitrification was long delayed. But the usual sequence of events took place, namely, at first some purification but no nitrite or nitrate production. Later nitrite, but no nitrate. Later still relative disappearance of nitrites and presence of nitrates.

1st Series of Experiments. A filter treats "heated" Sewage; B filter treats "unheated" Sewage.

Summary Remarks.

On the other hand, A filter giving somewhat parallel results as regards oxygen absorbed from permanganate behaved quite differently as regards nitrification. For a long time the effluent contained no nitrites or nitrates. Later traces of nitrite appeared, and as time went on the nitrite was present in such amount as partially to vitiate the permanganate results. No nitrates, however, were formed. It is difficult to explain the presence of nitrites unless on the assumption that either some nitrite-producing bacteria in some way entered the filter and multiplied therein, or that nitrites can be formed by sporing bacteria. The latter explanation, however, would be considered erroneous by Winogradsky and others.

Four sets of samples were examined for free and albuminoid ammonia, with results as follows :—

——	Liquid being treated (settled sewage).		Effluent from A filter (treating sewage previously *heated*).		Effluent from B filter (treating sewage *not* previously heated).	
	Free.	Albuminoid.	Free.	Albuminoid.	Free.	Albuminoid.
April 21st	6·44	1·04	5·488	·304	3·788	·256
„ 24th	10·12	1·44	8·688	·416	7·168	·416
„ 27th	9·72	1·24	8·688	·368	7·888	·336
May 2nd	6·72	·64	2·448	·368	1·808	·336
Averages	**8·25**	**1·09**	**6·328**	**·364** (66 per cent. purification.)	**5·163**	**·336** (69 per cent. purification.)

One set of samples (May 2nd) were examined bacteriologically with results as follows :—

——	Liquid being treated (settled sewage) Per c.c.	Effluent from A filter (treating sewage previously *heated*). Per c.c.	Effluent from B filter (treating sewage *not* previously heated). Per c.c.
B. coli test	10,000	1	10,000
B. enteritidis sporogenes test	1,000	10	100
Total number of microbes (agar at 37° C.)	1,450,000	171,000	130,000
Nitroso-bacteria (nitrite-producing bacteria)	1,000	1,000	10,000

As previously, the effluent from A filter contained the most bacteria. B. coli was present in 1 c.c. but not $\frac{1}{10}$ c.c. Possibly the heating apparatus was temporarily inefficient, but compared with the 10,000 per c.c. in the B filter effluent, B. coli may be said to have been practically absent in the effluent from the A filter. The nitrite-producing bacteria, however, were numerous in the A filter effluent, which accounts for the nitrites observed in the chemical analysis of this effluent. The nitrite-producing bacteria were also numerous in the B filter effluent, although no nitrites were found on chemical analysis, but this result was due to complete nitrification; and it is customary to find that the effluent from a mature sewage filter yields on chemical analysis nitrates, but practically no nitrites, and yet shows on bacteriological analysis numerous nitrite-producing bacteria.

On May 2nd a radical alteration was made in the method of working. In connexion with the foot of each filter a small hole was bored in the position marked * in Fig. 3. By means of a bent piece of wire inserted in the hole, the liquid escaping from the filter dribbled into a funnel which rested in the mouth of a glass bottle.

The filters were now worked as continuous filters with periods of complete rest. The working period was about two hours and the resting period about 22 hours. The filtrates were measured each day.

The filters were worked in this manner from May 3rd to May 29th (both inclusive), during which period they dealt with volumes of settled sewage as under :—

A filter (treating sewage previously *heated*).	B filter (treating sewage *not* previously heated).
37,840 c.c.	36,220 c.c.

1st Series of Experiments. A filter treats "heated" Sewage; B filter treats "unheated" Sewage.

The chemical analyses of the effluents yielded results as follows:—

Oxygen absorbed from permanganate, 4 hours at laboratory temperature. Parts per 100,000.

—	Liquid being treated (settled sewage).	Effluent from A. filter (treating sewage previously *heated*).	Effluent from B. filter (treating sewage *not* previously heated).
May 3rd	2·5	2·20	1·68
„ 4th	2·9	2 04	1·40
„ 5th	2·3	2·12	1·44
„ 6th	2·5	2·28	1·20
„ 7th	3·3	2·20	1·16
„ 8th	2·5	2·12	1·24
„ 9th	1·9	1·96	1·00
„ 11th	2·5	2·04	1·00
„ 12th	2·0	1·76	·92
„ 13th	2·1	2·00	·84
„ 14th	2·9	1·92	·88
„ 15th	2·7	1·72	·96
„ 16th	3·6	2·10	1·30
„ 18th	2·6	1·96	·88
„ 19th	3·5	2·12	1·08
„ 20th	2·5	2·28	1·00
„ 21st	3·2	2·60	1·16
„ 22nd	3·7	2·68	1·20
„ 23rd	4·0	2·56	1·48
„ 25th	3·0	2·48	1·16
„ 26th	3·8	2·40	1·32
„ 27th	3·4	2 40	1·28
„ 28th	5·2	2·56	1·16
„ 29th	5·8	3·08	1·88
Averages	**3·1**	**2·23** (28 % purification).	**1·19** (61 % purification).

These results, however, so far as the A filter is concerned, are misleading. This effluent contained nitrites in considerable amount, which, as well as the oxidisable matter, reduced the permanganate, thus rendering the results of indeterminate value.

As regards nitrites, the effluents from A filter invariably gave a positive result, and usually the reaction was very marked. The effluent from B filter on the other hand either gave a completely negative result or only slight traces.

In respect of nitrates an opposite result was obtained. The A filter effluent, except on one occasion when the result was doubtful, always yielded negative results. The effluent from B filter always gave positive results, and the average amount of nitrate, based on 24 separate analyses, was 1·7 (parts per 100,000).

Eleven sets of samples were examined for free and albuminoid ammonia.

Parts per 100,000.

—	Liquid being treated (settled sewage).		Effluent from A filter (treating sewage previously *heated*).		Effluent from B filter (treating sewage *not* previously heated).	
	Free.	Albuminoid.	Free.	Albuminoid.	Free.	Albuminoid.
May 5th	2·72	·36	5·088	·224	3·888	·224
„ 8th	2·72	·84	2·288	·144	2·048	·144
„ 11th	3·56	·62	2·224	·152	1·944	·136
„ 12th	2·86	·46	2·344	·136	1·984	·128
„ 15th	4·96	·48	2·144	·132	1·944	·136
„ 19th	5·86	·68	3·624	·168	3·544	·152
„ 20th	5·86	·52	3·864	·160	3 744	.160
„ 22nd	3·56	·38	3·874	·160	3·744	·144
„ 25th	6·46	·44	2·984	·144	2·744	·128
„ 27th	6·56	·80	4·064	·224	3·544	·168
„ 29th	8·16	1.02	5·184	·344	5·064	·272
Averages	**4·84**	**·6**	**3·425**	**·18** (70 % purification).	**3·108**	**·163** (73 % purification).

It will be noted that, as judged by the albuminoid ammonia test, the effluents from A and B filters gave approximately the same degree of purification, namely, 70 and 73 per cent. respectively.

Fourteen sets of samples were examined as follows :—

Stoppered bottles were filled completely full of the various liquids, each bottle having first received 10 drops of a one per cent. solution of tartrate of iron. The bottles were incubated at 30° C. for periods varying from 24 to 39 days. Each set comprised samples of the following liquids :—

(*a*) Settled sewage (*not* heated) ; (*b*) settled sewage (*heated*, under same conditions as liquid going on to A filter) ; (*c*) effluent from B filter (*not* heated) ; (*d*) effluent from A filter (*heated*). It is to be noted that both (*a*) and (*b*) invariably turned black ; (*c*) never turned black, except the last sample, which showed some blackening ; (*d*) sometimes showed a black colour which varied in degree, but at other times no blackening was noted.

1st Series of Experiments. A filter treats "heated" Sewage; B filter treats "unheated" Sewa

The bacteriological analyses yielded results as follows :—

On May 5, 7, 8, 9, 11, 12, 13, 14, 15, 16, 18, 19, 21, 22, 23, 25, 26, 27, 28, 29, the effluents from A filter were examined for B. coli. With one exception (May 9th + 1 c.c. ; — ·1 c.c.) no B. coli were found in 1 c.c. of the samples.

On May 6th and 20th, a more complete bacteriological analysis was made with results as follows :—

—		Liquid being treated (settled sewage). Per c.c.	Effluent from A filter (treating sewage previously *heated*). Per c.c.	Effluent from B filter (treating sewage *not* previously heated). Per c.c.
B. coli	May 6	100,000	None.	100,000
	„ 20	10,000	None.	10,000
B. enteritidis sporogenes test	May 6	100	10	10
	„ 20	1,000	10	10
Total number of bacteria (agar at 37° C.)	May 6	6,600,000	1,080,000	1,010,000
	„ 20	2,300,000	1,000,000	400,000
Nitroso-bacteria	May 6	1,000	1	10,000
	„ 20	100	10,000	100,000

It will be seen that, as previously, the effluent from A filter contained more microbes than the effluent from B filter. Further, whereas the effluent from B filter contained from 10,000 to 100,000 B. coli, the effluent from A filter contained no B. coli in 1 c.c.

In brief summary of the foregoing results the effluents from A and B may be compared as follows :—

Bacteriological Results.	Effluent from A filter.	Effluent from B filter.
Total number of Microbes	Very numerous, and more in A. than B.	Also numerous, but less in B than A.
B. Coli	None in 1 c.c.	10,000 to 100,000 per c.c.
Chemical Results.		
Oxygen absorbed from permanganate	Only 28 % purification, but results inconclusive owing to presence of nitrites.	61 % purification.
Albuminoid Ammonia	70 % purification.	73 % purification.
Nitrites	Present in relatively large amount.	Practically absent.
Nitrates	Absent.*	1·7 parts per 100,000.

2nd SERIES OF EXPERIMENTS.

2nd Series of Experiments. A filter now treats "unheated" Sewage; B filter now treats "heated" Sewage.

A *filter now treats "unheated" Sewage*; B *filter now treats "heated" Sewage.*

On the evening of May 29th an important alteration in the experiment was made.

Y interchanged with Z (& called Z) & Z with Y (& called Y)
M „ „ N & N „ M.

(*See* Fig. 1.)

So that in future B filter (mature, previously treated with "unheated" sewage) receives *heated* sewage, and A filter (not entirely mature, previously treated with "heated" sewage) receives "*unheated*" sewage.

The results obtained under the new conditions from May 30th to June 23rd may be summarised as follows :—

During this period the filters dealt with volumes of settled sewage as follows :—

A filter.	B filter.
27,985 c.c.	29,840 c.c.

* It is conceivable, however, that if the experiment had been continued still longer, nitrates might have appeared in the A filter effluent. But in this connection it should be noted that from April 20th to May 29th the A filter effluent produced nitrite in conspicuous amount, and if this was merely preparatory to nitrate formation the delay in the production of the latter was inexplicably long.

2nd Series of Experiments. A filter now treats "unheated" Sewage; B filter now treats "heated" Sewage.

Oxygen absorbed from permanganate (at laboratory temperature). *Parts per* 100,000.

——	Liquid being treated (settled sewage).		Effluent from A filter (now receiving "*unheated*" s. sewage).		Effluent from B filter (now receiving "*heated*" s. sewage).	
	3 minutes.	4 hours.	3 minutes.	4 hours.	3 minutes.	4 hours.
May 30th, 1903	—	5·9	—	2·92	—	2·08
June 1st „	—	4·5	—	3·22	—	1·80
„ 2nd „	—	4·0	—	3·44	—	1·84
„ 3rd „	—	3·2	—	2·60	—	1·52
„ 4th „	2·4	4·6	1·72	2·84	·6	1·32
„ 5th „	—	5·6	—	3·00	—	1·80
„ 6th „	—	4·4	—	3·00	—	1·52
„ 8th „	2·3	4·2	1·68	2·88	·68	1·56
„ 9th „	—	4·9	—	3·36	—	2·32
„ 10th „	1·6	3·7	2·12	3·28	·80	1·76
„ 11th „	3·1	5·1	1·24	2·52	·60	1·56
„ 12th „	—	5·0	—	2·64	—	1·60
„ 13th „	1·6	3·6	1·08	2·40	·76	1·60
„ 14th „	1·1	3·0	1·04	1·96	·56	1·36
„ 16th „	·99	2·9	·72	1·80	·48	1·20
„ 17th „	1·3	3·3	·824	1·72	·60	1·20
„ 18th „	1·3	3·3	·72	1·64	·52	1·08
„ 19th „	·9	2·5	·60	1·60	·56	1·32
„ 20th „	·8	2·2	·56	1·48	·40	1·04
„ 22nd „	·81	1·9	·56	1·28	·48	1·04
„ 23rd „	·84	2·0	·52	1·28	·44	1·08
Averages	**1·46**	**3·8**	**1·03**	**2·42** (36 per cent. purification.)	**·57**	**1·5** (60 per cent. purification.)

It will be noted that the purification (4 hours' absorption) in effluents A and B was 36 and 60 per cent. respectively. But if we deduct the difference between the A and B 3 minutes' absorption figures from the 4 hours' A filter absorption figures, the percentage purification equals 48 instead of 36. Moreover, it will be seen that after June 14th the results as regards the A filter effluent improved. At or about this period the A filter began to produce nitr*a*tes with parallel diminution in the amount of nitr*i*tes.

As regards nitr*a*tes and nitr*i*tes the following results were obtained :—

——	A Filter (now receiving "*unheated*" Sewage).	B Filter (now receiving "*heated*" Sewage).	A Filter (now receiving "*unheated*" Sewage).	B Filter (now receiving "*heated*" Sewage).
	Nitrates (*i.e.*, nitrogen as nitrates).		Nitrites.	
May 30th	—	1·0		
June 1st	—	2·0		
„ 2nd	—	1·0		
„ 3rd	—	1·0		
„ 4th	Practically negative	1·75	Strong positive result.	
„ 5th	„ „	1·75		
„ 6th	„ „	1·75		
„ 8th	„ „	1·75		
„ 9th	„ „	·75		
„ 10th	„ „	1·75		
„ 11th	„ „	1·75		Only traces.
„ 12th	Distinct traces	2·0		
„ 13th	„ „	1·25		
„ 15th	1·5	1·75		
„ 16th	1·5	1·75	Reaction gradually grew less until only traces present.	
„ 17th	1·5	1·75		
„ 18th	1·5	1·75		
„ 19th	·75	1·25		
„ 20th	1·0	2·0		
„ 22nd	1·5	1·75		
„ 23rd	1·5	1·75		

The effluents from the A filter at first gave a strong positive reaction with the test for nitr*i*tes. Later (from about June 11th) the reaction gradually grew less, until only traces could be detected. Coincidently with the decrease in nitr*i*tes, nitr*a*tes made their appearance in the effluent. Thus the A filter, which previously, when treated with "*heated*" sewage, showed in the effluents nitr*i*tes but no nitr*a*tes, when treated with "*unheated*" sewage soon ceased to give a distinctly positive result with the nitr*i*te test and concurrently produced nitr*a*tes in appreciable amount.

2nd Series of Experiments. A filter now treats "unheated" Sewage; B filter now treats "heated" Sewage.

The B filter, on the other hand, which previously had been matured with "*unheated*" sewage and which yielded nitr*a*tes but only traces of nitr*i*tes, remained unaffected by the change from "*unheated*" to "*heated*" sewage.

Eight sets of samples were examined for free and albuminoid ammonia.

Parts per 100,000.

—	Liquid being treated (Settled Sewage). Free.	Liquid being treated (Settled Sewage). Albuminoid.	Effluent from A Filter (now receiving "*unheated*" Sewage). Free.	Effluent from A Filter (now receiving "*unheated*" Sewage). Albuminoid.	Effluent from B Filter (now receiving "*heated*" Sewage). Free.	Effluent from B Filter (now receiving "*heated*" Sewage). Albuminoid.
June 2nd - -	7·76	·86	3·824	·216	5·144	·224
„ 5th - -	7·66	1·15	4·824	·248	4·744	·248
„ 9th - -	8·96	·66	5·544	·272	6·344	·26
„ 11th - -	9·86	·72	5·944	·248	5·544	·252
„ 15th - -	6·66	·592	4·744	·224	5·364	·224
„ 19th - -	6·36	·7	4·544	·208	4·184	·208
„ 22nd - -	4·36	·42	3·144	·168	3·224	·176
„ 23rd - -	4·06	·4	3·144	·152	3·144	·184
Averages -	**6·96**	**·687**	**4·464**	**·217** 68% purification	**4·711**	**·222** 66% purification

It is apparent that both filters (A and B) were, as judged by the albuminoid ammonia test, producing a nearly similar degree of purification.

The bacteriological analyses yielded results as follows: On June 2nd, 3rd, 10th, 12th, 19th and 23rd, bacteriological analyses were made with the following results :—

—	June	Liquid being treated (settled sewage) Per c.c.		Effluent from A filter now receiving "*unheated*" sewage. Per c.c.		Effluent from B filter now receiving "*heated*" sewage. Per c.c.	
B. coli.	2nd	100,000		100,000		1	
	3rd	1,000		1,000		1	
	10th	10,000		10,000		1	
	12th	10,000		100,000		None	
	19th	10,000		10,000		None	
	23rd	1,000		1,000		None	
B. enteritidis sporogenes test.	2nd	100		10		1	
	3rd	100		10		10	
	10th	100		100		10	
	12th	100		100		10	
	19th	100		100		10	
	23rd	1,000		1		10	
Total number of bacteria.	2nd	2,400,000	Agar at 37° C.	480,000	Agar at 37° C.	910,000	Agar at 37° C.
	3rd	10,000,000		290,000		At least 100,000 (plates overgrown).	
	10th	5,000,000		1,070,000		1,600,000	
	12th	13,000,000	Gelatine at 20° C.	700,000	Gelatine at 20° C.	70,000	Gelatine at 20° C.
	19th	9,300,000		110,000		8,000	
	23rd	500,000		49,000		24,000 (B. fluorescens liquefaciens very numerous.)	
Nitroso-bacteria.	2nd	10		10,000		10,000	
	3rd	1,000		100		1,000	
	10th	10		1,000		10,000	
	12th	10		10,000		10,000	
	19th	100		100		10,000	
	23rd	100		100		100,000	

2nd Series of Experiments. A filter now treats "unheated" Sewage; B filter now treats "heated" Sewage.

B. coli.—The effluent from A filter, which contained no B. coli during the time it had been treated with *heated* sewage, now contained from 1,000 to 100,000 B. coli per c.c., as a result of dosing the filter with *unheated* sewage.

On the other hand, B filter, which during the time it had received *un-heated* sewage contained B. coli in abundance, now ceased rapidly to yield practically any B. coli as a result of dosing the filter with *heated* sewage. This result would seem to indicate that B. coli having no essential concern in the purification process failed to maintain its existence in the B. filter under the altered condition of working. From the epidemiological point of view this result is of interest, as it indicates that pathogenic microbes (*e.g.* B. typhosus) accidentally introduced with sewage into a biological filter would be most unlikely to *multiply* in the filter, and would in all probability be either washed out of the filter, or, if retained in the filter, rapidly lose their vitality.

Total number of Microbes.—The results were variable and the figures do not lend themselves to comparative treatment. It will be remembered that previously the effluent from A filter always contained more microbes than the effluent from B filter. On the whole this state of things was not altered by the altered conditions of working, but it is conceivable that if the experiment had been continued over a longer period the effluent from B filter might in time have contained more bacteria than the effluent from the A filter.

Nitroso-bacteria.—The result showed that the effluents from both filters contained more nitrite producing bacteria than the sewage, but the effluent from B filter contained more of the microbes than the effluent from A filter.

3rd SERIES OF EXPERIMENTS.

3rd Series of Experiments. A filter now receives sterile sodium chloride solution; B filter still treats "heated" Sewage.

A *filter now receives sterile sodium chloride* solution*; B *filter still treats "heated" sewage.*

On June 24th, 1903, a complete alteration in the mode of working was commenced.

B Filter.—By blocking the opening of K (*see* Figure 1), double the quantity of settled sewage was allowed to pass along J. The B filter thus received twice the volume of *heated* sewage. Later, however (July 2nd), as the filter showed some signs of deterioration the rate of flow of the settled sewage was somewhat reduced.

A Filter.—This filter had gradually become mature after treating it with *unheated* instead of *heated* sewage, and was yielding nitrates and hardly any nitrites; it was now dosed with *sterile* sodium chloride solution (0·5 per cent. Na Cl). The tray and vessel Y were first cleaned and the sodium chloride solution allowed to drop into Y from a convenient apparatus (*see* Figure 4).

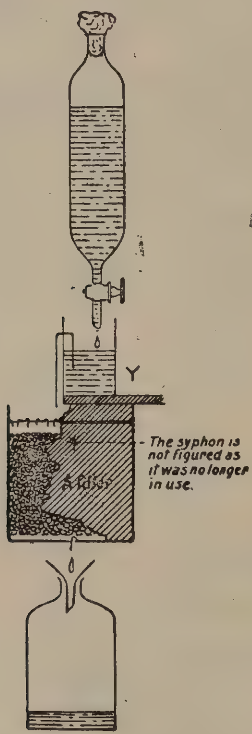

FIGURE 4.

From June 24th to July 15th, the following results were obtained.

During this period the filters dealt with volumes of liquid as follows :—

A Filter.	B Filter.
32,455 c.c. of *sterile* sodium chloride solution.	38,550 c.c. of "*heated*" *settled* sewage.

* Sodium chloride was added in case distilled water *alone* might exercise a bactericidal action.

Oxygen absorbed from permanganate, 4 hours at laboratory temperature. Parts per 100,000.

3rd Series of Experiments. A filter now receives sterile sodium chloride solution ; B filter still treats "heated" Sewage.

——	Effluent from A filter (now receiving *sterile* sodium chloride solution).	Effluent from B filter (receiving "*heated*" settled sewage).	Liquid being treated on B filter (settled sewage).
June 24th	0·37*	0·92	1·9
„ 25th	0·25	1·00	2·1
„ 26th	0·20	1·08	1·7
„ 27th	0·10	·96	2·3
„ 28th	0·11	—	—
„ 29th	0·11	1·16	3·2
„ 30th	0·13	1·32	2·9
July 1st	0·20	1·80	2·2
„ 2nd	0·29	1·08	4·2
„ 3rd	0·28	1·40	2·0
„ 4th	0·32	1·00	3·7
„ 5th	0·33	1·16	3·7
„ 6th	0·36	1·16	2·5
„ 7th	0·33	1·12	3·6
„ 8th	0·24	·92	2·5
„ 9th	0·35	1·32	2·4
„ 10th	0·29	1·36	4·2
„ 11th	0·24	1·24	4·4
„ 12th	0·16	—	—
„ 13th	0·16	1·28	5·9
„ 14th	0·16	1·24	4 9
„ 15th	0·17	1·24	3·3
Averages	**0·23**	**1·18** (62% purification.)	**3·18**

A filter.—The filtrate from the A filter, which at first was quite transparent-looking, gradually became more and more cloudy. On standing, the particles which caused the cloudiness settled at the foot and clung to the sides of the bottle used for collecting the effluent. These solids appeared to be of a flocculent nature and were probably derived from the organic deposit which had previously collected on the surfaces of the coke particles.

It will be noted that even at the end of the experiment the filtrate contained an appreciable amount of oxidisable matter. The average amount was 0·23, so that in the aggregate the organic matter yielded up by the A filter was considerable. From June 27th to 30th the amount of organic matter leaving the filter was less than during the first few days of the experiment and seemed to have reached a fairly constant figure. But from July 1st to 11th the figures were higher and this appeared to coincide with the presence in the effluent of the flocculent deposit already referred to. After the latter date the amount of organic matter in the effluent again became less although it was still quite appreciable.

B filter.—The B filter previously matured with *unheated* sewage continued to purify the *heated* sewage and effected a purification of 62 per cent.

Nitrites and Nitrates.

A filter.—During the whole of the period (June 24th to July 15th) the effluent from the A filter yielded faint traces of nitrites and appreciable traces of nitrates (about ·1 but less than ·2 parts per 100,000). Apparently the nitrifying bacteria persisted in the filter and continued to act on the organic matter which had accumulated on the surfaces of the coke.

B filter.—During the above period (June 24th to July 15th) the effluent contained only traces of nitrite. Twenty analyses on different days of the effluent as regards nitrates gave an average of 1·36 parts per 100,000.

Free and Albuminoid Ammonia.

Twelve sets of samples were examined for free and albuminoid ammonia with the following results:—

A. Filter. Parts per 100,000.

——	Free Ammonia.† A filter Effluent.	Albuminoid Ammonia.† A filter Effluent.
June 24th	·012	·0224
„ 25th	·012	·0225
„ 26th	·0136	·0222
„ 27th	·016	·0176
„ 28th	·0136	·016
„ 29th	·0176	·02
July 1st	·0352	·0248
„ 3rd	·056	·0336
„ 6th	·0576	·0544
„ 9th	·0816	·0424
„ 13th	·0544	·0392
„ 15th	·0424	·0304
Averages	**·0343**	**·0288**

* The oxidisable matter in the sodium chloride solution was also determined and allowed for in calculating the above figures.

† The free and albuminoid ammonia in the saline solution was also determined and allowed for in calculating the above figures.

3rd Series of Experiments. A filter now receives sterile sodium chloride solution; B filter still treats "heated" Sewage.

It will be noted that even at the end of the experiment the effluents contained free and albuminoid ammonia in very appreciable amount. In the aggregate a good deal of organic matter was washed from the filter. Further, as in the oxygen absorbed from permanganate experiments, there was a time (early part of July) when the results were specially bad, owing seemingly to a breaking down and washing out of the organic material previously stored in the filter.

B filter. Parts per 100,000.

—	Free Ammonia.		Albuminoid Ammonia.	
	B filter Effluent.	Settled Sewage (*heated*).	B filter Effluent.	Settled Sewage. (*heated*).
June 24th	2·74	4·36	·152	·38
„ 25th	2·344	4·36	·136	·44
„ 26th	2·244	3·36	·144	·36
„ 29th	2·344	3·56	·192	·32
July 1st	2·644	3·96	·176	·32
„ 3rd	2·944	4·86	·176	·42
„ 6th	3·334	5·86	·168	·42
„ 9th	3·544	6·36	·168	·42
„ 13th	4·064	6·66	·184	·48
„ 15th	4·864	6·66	·164	·38
Averages	**3·1066**	**5·0**	**·1658** (57% purification).	**·394**

It will be seen that the purification as measured by the albuminoid ammonia test was 57 per cent. The B filter, it will be remembered, originally had been matured with *unheated* sewage. Despite the change from *unheated* to *heated* sewage the filter continued its work of purification.

On June 30th, July 4th, 6th, 10th and 15th, bacteriological analyses were made with the following results:—

—		Liquid being treated on B filter (examined before being "*heated*"). Per c.c.	Effluent from A filter now receiving sodium chloride solution. Per c.c.	Effluent from B filter receiving "*heated*" settled sewage. Per c.c.
B. coli.	30th June	10,000	Negative 1 c.c.	Negative 1 c.c.
	4th July	10,000	1	„ „
	6th „	10,000	1	„ „
	10th „	100,000	None	„ „
	15th „	1,000	None	„ „
B. enteritidis sporogenes test.	30th June	100	1	1
	4th July	100	1	1
	6th „	1,000	1	1
	10th „	100	None	1
	15th „	10	None	1
Total number of bacteria agar at 37° C.	30th June	300,000	51,000	370,000
	4th July	770,000	72,000	380,000
	6th „	2,190,000	390,000	130,000
	10th „	12,700,000	310,000	380,000
	15th „	600,000	136,000	148,000
Nitroso-bacteria.	30th June	1	? 1	1,000
	4th July	10	10	1,000
	6th „	1	None	10,000
	10th „	10	None	100
	15th „	100	None	1,000

B. coli.—The effluent from the A filter which, it will be remembered, previously contained from 1,000 to 100,000 B. coli now contained practically no B. coli when treated with sterile sodium chloride solution.

The effluent from the B filter continued to yield a liquid free from B. coli.

Total Number of Microbes.—The effluent from the A filter continued to yield bacteria in great numbers despite the fact that the filter was being treated with sterile sodium chloride solution. Moreover, the number on July 6th and 10th was greater than on June 30th and July 4th, probably due to the breaking down of the organic matter which had accumulated on the surfaces of the coke particles.

The effluent from the B filter contained an increased number of microbes. In this connection it will be remembered that it was previously noted that a filter dealing with *heated* sewage is apt to yield more bacteria in the effluent than a filter dealing with *unheated* sewage.

Nitroso-bacteria.—The A filter, despite the fact that traces of nitr*i*te and nitr*a*te still appeared in the effluent soon ceased to yield any nitr*i*te—producing bacteria in the effluent. Presumably, however, some of the microbes must still have been exercising their functions in the body of the filter although not appearing in the effluent.

The effluent from the B filter continued to yield numerous nitr*i*te-producing bacteria.

3rd Series of Experiments. A filter now receives sterile sodium chloride solution; B filter still treats "heated" Sewage.

4th SERIES OF EXPERIMENTS.

4th Series of Experiments. A filter again treats "unheated" Sewage; B filter still treats "heated" Sewage.

A filter again treats "unheated" sewage; B filter still treats "heated" sewage.

On July 16th the method of treatment was altered as follows:—

B filter continued as before to treat *heated* settled sewage.

A filter was now treated with *unheated* sewage instead of sterile saline solution. The same apparatus being used to feed Y syphon. (*See* Fig. 4.)

From July 16th to 30th the filters dealt with volumes of liquid as follows:—

A filter.	B filter.
15,400 c.c. *Unheated* sewage.	14,945 c.c. *Heated* sewage.

Oxygen absorbed from permanganate, 4 hours at ordinary temperature. Parts per 100,000.

——	Liquid being treated (settled sewage).	Effluent from A filter (treating "*unheated*" settled sewage).	Effluent from B filter (treating "*heated*" sewage).
July 16th -	5·9	1·44	1·16
" 17th -	4·8	1·52	1·44
" 18th -	5·0	1·72	1·48
" 20th -	5·5	1·48	1·28
" 28th -	1·8	1·44	1·24
" 29th -	3·4	1·56	1·40
" 30th -	2·5	1·84	1·16
Averages -	**4·13**	**1·57** (62 % purification.)	**1·16** (71 % purification.)

Despite its previous treatment with sterile saline solution the A filter was able to produce, even from the outset, a fair degree of purification (62 per cent.) of the "unheated sewage."

The B filter continued to deal satisfactorily with the "heated" sewage, the purification here being 71 per cent.

Nitrites and Nitrates.

—	Nitr*i*tes.		Nitr*a*tes.	
	Effluent from A filter.	Effluent from B filter.	Effluent from A filter.	Effluent from B filter.
July 16 - - - -	Traces.	Traces.	Traces.	2
" 17 - - - -				1·75
" 18 - - - -				2
" 20 - - - -				2
" 21 - - - -				2·25
" 22 - - - -			Distinctly positive.	2
" 23 - - - -			" "	2·5
" 27 - - - -			·5	1·75
" 28 - - - -			·5	1·75
" 29 - - - -			·75	1·75
" 30 - - - -			·75	2·25

As regards nitr*i*tes the effluents from both the A and B filters contained traces of nitr*i*te.

In respect of nitr*a*tes, the A filter effluent contained only an unappreciable a mount of nitr*a*te until about July 22nd. Thereafter the amount of nitrate produced was quite appreciable. The B filter continued to oxidise the nitrogenous matter of the sewage.

4th Series of Experiments. A filter again treats "unheated" Sewage; B filter still treats "heated" Sewage.

Free and Albuminoid Ammonia. Parts per 100,000.

—	Liquid being treated (Settled Sewage).		Effluent from A filter receiving "unheated" Sewage.		Effluent from B filter receiving "heated" Sewage.	
	Free.	Albuminoid.	Free.	Albuminoid.	Free.	Albuminoid.
July 17th - -	8·86	·38	5·44	·136	4·944	·184
„ 30th - -	7·16	·36	5·144	·2	3·944	·18
Averages - -	**8·01**	**·37**	**5·292**	**·168** (54 per cent. purification.)	**4·444**	**·182** (51 per cent. purification.)

Only two samples were examined; the percentage degree of purification (albuminoid ammonia) was 54 and 51 as regards the effluents from the A and B filters respectively.

On July 29th, a bacteriological analysis was made with the following results :—

———	Liquid being treated. Settled sewage examined before being heated.	Effluent from A filter receiving "unheated" settled sewage.	Effluent from B filter receiving "heated" sewage.
	Per c.c.	Per c.c.	Per c.c.
B. coli test - - - - - -	10,000	1,000	None
B. enteritidis sporogenes test -	10	1	1
Total number of bacteria (agar at 37° C.) - - - -	488,000	90,000	118,000
Nitroso-bacteria - - - -	1	100	1,000

It will be noted that the effluent from B filter contained no B. coli, but a larger total number of microbes than the effluent from A filter. The effluent from A filter contained 1,000 B. coli per c.c.

5th Series of Experiments. A filter still treats "unheated" Sewage; B filter now treats "completely sterilised" Sewage.

5th SERIES OF EXPERIMENTS.

A filter still treats "unheated" sewage; B *filter now treats "completely sterilised"* sewage.*

On July 31st the following change was made.

B filter received completely *sterilised* settled sewage instead of heated settled sewage. The sterilised sewage was allowed to drop into Z (Figure 1) from a similar piece of apparatus to that shown in Figure 4. The siphon vessel Z (*see* Figure 1) was first thoroughly cleaned out, as it was full of sewage fungus.

A filter still received "*unheated*" settled sewage.

The experiment lasted from July 31st to August 10th. During this period the filters dealt with volumes of liquid as under :—

A filter.	B filter.
12,880 c.c. of "*unheated*" settled sewage.	11,970 c.c. of *sterilised* sewage.

Oxygen absorbed from permanganate, 4 hours at laboratory temperature. Parts per 100,000.

—	Liquid being treated on A filter ("*unheated*" settled sewage).	Effluent from A filter.	Liquid being treated on B filter (completely *sterilized* settled sewage).	Effluent from B filter.
July 31st - - - -	2·3	1·64	2·8	2·04
August 1st - - -	2·4	1·76	3·6	1·92
„ 2nd - - -	4·3	1·36	1·6	1·28
„ 3rd - - -	2·5	1·32	1·2	·92
„ 4th - - -	1·1	1·04	1·7	·76
„ 5th - - -	1·1	1·16	2·2	1·00
„ 6th - - -	4·1	1·20	3·5	1·20
„ 8th - - -	4·1	1·80	2·2	1·20
Averages - - -	**2·73**	**1·41** (48 % purification).	**2·35**	**1·29** (45 % purification).

It will be seen that A and B filters effected about the same percentage purification although dealing with "*unheated*" sewage and *sterilised* sewage respectively.

The effluents were tested for nitr*i*tes and nitr*a*tes on July 31st, August 1st, 2nd, 3rd, 4th, 5th, 6th, and 8th. Both the A and B effluents contained traces of nitr*i*te. The average amount of nitr*a*te produced was ·7 (A filter) and 1·09 (B filter) parts per 100,000. Thus both filters, the one (A) dealing with "*unheated*" sewage and the other (B) with *sterilised* sewage were producing nitr*a*tes and traces only of nitr*i*te.

The filters were rested on August 11th, and on the 12th were worked on fresh lines.

* That is, sewage heated so as to destroy both spores and bacilli.

6th SERIES OF EXPERIMENTS.

6th Series of Experiments. A filter now treats "sterile dilute urine;" B filter still treats "completely sterilised" Sewage.

A filter now treats "sterile dilute urine"; B filter still treats "completely sterilised" sewage.

On August 12th the A filter, which had been treating "*unheated*" settled sewage, was now called upon to treat daily (except when rested) a mixture of 10 c.c. of sterile urine* in 1000 c.c. of sterile distilled water. The apparatus used is shown in Figure 5.

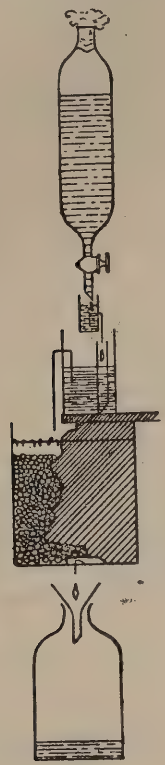

FIGURE 5.

The B filter still received *sterilised* settled sewage (1,000 c.c. daily, except when rested), a duplicate piece of apparatus to that in use in connexion with A filter being used (*see* Figure 5).

The experiment was in progress until September 2nd, and during this period the filters dealt with volumes of liquid as follows :—

A filter.	B filter.
18,000 c.c. of *sterile urine* and water.	18,000 c.c. of *sterilised* settled sewage.

Oxygen absorbed from permanganate, 4 *hours at laboratory temperature. Parts per* 100,000.

——	Effluent from A filter (receiving sterile *urine* and water).	Effluent from B filter (receiving *sterilised* settled sewage).	Liquid being treated on B filter (sterilised settled sewage).
August 13th - - -	—	1·29	5·98
" 14th - -	·63	1·33	2·93
" 15th - - -	·46	1·63	3·45
" 17th - - -	·43	1·49	3·51
" 18th - - -	·44	1·22	3·33
" 20th - - -	—	1·10	2·30
" 21st - - -	·38	1·06	2·69
" 24th - - -	·25	·84	2·23
" 27th - - -	·37	·87	1·18
" 28th - - -	·36	1·08	3·19
" 31st - - -	·26	1·01	3·22
September 1st - - -	·38	1·16	3·38
" 2nd - - -	·36	·92	2·46
Averages - - -	**·36**	**1·15** (62 per cent. purification.)	**3·06**

It will be noted that the A filter, although treated with 1 per cent. sterile urine, yielded a filtrate which only absorbed ·36 part per 100,000 parts of oxygen.

The B filter continued to purify the sterilised settled sewage, the purification being 62 per cent.

* Pasteur filtered, not heated.

6th Series of Experiments, A filter now treats "sterile dilute urine"; B filter still treats "completely sterilised" Sewage.

——	Nitrites.		Nitrates.	
	Effluent from A filter (treating sterile urine and water).	Effluent from B filter (treating sterilised settled sewage).	Effluent from A filter (treating sterile urine and water).	Effluent from B filter (treating sterilised settled sewage).
August 18th - - -	+	+	1·75	1·25
" 19th - - -	+	+	2·00	1·25
" 20th - - -	+	+	1·50	1·00
" 21st - - -	+	+	2·00	1·75
" 22nd - - -	Traces.	Traces.	3 00	1·75
" 24th - - -	"	"	3·50	2·50
" 25th - - -	"	"	2·50	1·75
" 26th - - -	"	"	3·00	2·00
" 27th - - -	"	"	3·00	1·75
" 28th - - -	"	"	2·00	1·50
" 29th - - -	"	"	2·00	1·75
" 31st - - -	"	"	2·50	1·25
September 1st - -	"	"	3·00	1·50
" 2nd - -	"	"	3·00	2·00
		Averages - -	**2·48**	**1·64**

The effluents from both filters yielded at first a distinctly positive result with the test for nitr*i*tes. Later, however, the effluents contained traces only of nitr*i*te.

As regards nitrates, both effluents contained nitr*a*tes, and the averages were 2·48 (A filter) and 1·64 (B filter).

Samples were examined for free and albuminoid ammonia, with the following results :—

Parts per 100,000.

——	Effluent from A filter (treating sterile urine and water).		Effluent from B filter (treating sterilised settled sewage).		Liquid being treated on B filter (sterilised settled sewage).	
	Free.	Albuminoid.	Free.	Albuminoid.	Free.	Albuminoid.
August 12th - -	—	—	2·2	·23	5·08	·45
" 14th - -	1·37	·39	—	—	—	—
" 15th - -	—	—	3·04	·29	5·88	·66
" 19th - -	3·50	·08	—	—	—	—
" 20th - -	—	—	2·97	·22	6·30	·51
" 22nd - -	3·34	·10	2·73	·18	6·38	·30
" 24th - -	2·51	·02	—	—	—	—
" 26th - -	—	—	2·04	·11	5·62	·23
" 27th - -	3·45	·06	—	—	—	—
" 29th - -	4·58	·10	3·23	·14	6·28	·24
September 1st -	3·14	·10	—	—	—	—
Averages - -	**3·12**	**·121**	**2·67**	**·195** (51 per cent. purification.)	**5·92**	**·398**

It will be seen that, as judged by the albuminoid ammonia test, the B filter effected an average purification of 51% of sterilised settled sewage.

7th Series of Experiments. A filter now treats artificial "urea mixture"; B filter still treats "completely sterilised" Sewage.

7th SERIES OF EXPERIMENTS.

A filter now treats an artificial "urea mixture"; B filter still treats "completely sterilised" sewage.

On September 2nd the A filter received, instead of sterile urine and water, an artificial urea mixture (sterilised) having the following composition :—

1 gramme urea
1 " potassium sodium tartrate
·1 " " dihydric phosphate
·1 " magnesium sulphate
Distilled water 100 c.c.

The B filter continued to treat sterilised settled sewage.

From September 2nd to December 29th each filter received daily (except for occasional rests) 1 litre of liquid. The total amounts were :—

A filter	B filter
111,000 c.c. of sterile urea mixture.	111,000 c.c. of sterile sewage.

The results of the chemical and bacteriological examination of the effluents were as follows :—

7th Series of Experiments. A filter now treats artificial "urea mixture"; B filter still treats "completely sterilised" Sewage.

Oxygen absorbed from permanganate, 4 *hours at laboratory temperature. Parts per* 100,000.

——	Effluent from B filter (treating *sterilised* settled sewage).	Liquid being treated on B filter (*sterilised* settled sewage).
Sept. 4th	1·05	3·22
" 7th	·77	2·64
" 9th	·71	1·95
" 11th	·62	1·57
" 14th	·67	1·77
" 18th	·82	2·75
" 21st	·78	2·45
" 23rd	·84	1·93
" 25th	1·12	3·22
" 29th	·74	1·09
Dec. 20th	·72	2·80
" 21st	1·24	3·10
" 22nd	·80	1·90
" 23rd	·92	2·00
" 24th	·96	2·30
" 27th	1·00	2·20
Averages	**·86** (62% purification.)	**2·3**

It will be noted that, judged by the oxygen absorbed from permanganate test, the purification effected by the B filter was 62 per cent.

——	Nitrites.		Nitrates.	
	Effluent from A filter.	Effluent from B filter.	Effluent from A filter.	Effluent from B filter.
September 3rd	Trace.	Trace.	3·0	2·0
" 4th	"	"	2·0	2·0
" 5th	"	"	2·0	2·5
" 7th	"	"	2·0	2·5
" 8th	—	—	2·0	2·5
" 9th	Trace.	Trace.	2·5	2·5
" 10th	"	"	2·0	2·0
" 11th	"	"	1·5	2·5
" 15th	"	"	2·0	2·5
" 16th	"	"	2·0	1·5
" 17th	"	"	1·5	1·7
" 18th	"	"	1·75	2·0
" 19th	"	"	1·50	2·0
" 21st	"	"	2·0	2·0
" 22nd	"	"	2·0	2·0
" 23rd	"	"	1·7	1·5
" 24th	"	"	1·2	2·0
" 25th	—	—	2·0	2·0
" 28th	Trace.	Trace.	1·5	1·7
" 29th	"	"	1·7	2·5
" 30th	"	"	1·5	1·5
October 9th	"	"	2·2[illegible]	1·0
" 13th	"	"	1·25	1·25
" 21st	"	"	1·25	1·25
" 29th	"	"	1·50	1·25
November 6th	"	"	1·25	·75
" 11th	"	"	2·0	·75
" 19th	"	"	1·75	1·0
" 25th	"	"	1·75	1·0
December 2nd	"	"	2·0	1·0
" 10th	"	"	2·0	1·25
" 16th	"	"	1·75	1·25
" 21st	"	"	1·25	·75
" 22nd	"	"	1·25	·75
" 23rd	"	"	1·0	·5
" 24th	"	"	1·5	·75
" 27th	"	"	1·5	·75
" 28th	"	"	1·75	·75
" 29th	"	"	2·0	·75

7th Series of Experiments. A filter now treats artificial "urea mixture"; B filter still treats "completely sterilised" Sewage.

Both effluents contained nitrites, but the positive reaction was more marked in the case of the A filter effluent.

As regards nitrates, the A filter succeeded in oxidising the sterile urea mixture, and the B filter the sterilised sewage.

Samples were examined for free and albuminoid ammonia with the following results:—

Parts per 100,000.

—	Effluent from B filter (treating sterilised settled sewage).		Liquid being treated on B filter (sterilised settled sewage).	
	Free.	Albuminoid.	Free.	Albuminoid.
September 3rd - -	2·25	·03	5·92	·13
„ 7th - -	1·57	·08	4·70	·18
„ 10th - -	1·84	·08	5·10	·15
„ 15th - -	1·69	·07	4·57	·12
„ 17th - -	2·29	·09	4·88	·14
„ 21st - -	1·58	·04	5·26	·21
„ 23rd - -	2·73	·11	5·06	·12
„ 25th - -	3·10	·16	5·96	·12
„ 29th - -	1·54	·08	4·30	·17
December 22nd - -	2·414	·192	3·86	·26
„ 23rd - -	2·344	·128	5·36	·22
Averages - -	**2·122**	**·0963** (41 per cent. purification.)	**4·997**	**·1654**

The purification as measured by the albuminoid ammonia test was 41 per cent.

On December 21st the effluents from A and B filters were examined bacteriologically.

Neither of the effluents contained B. coli in 1 c.c., and the B. enteritidis sporogenes test also yielded negative results with 1 c.c.

The A filter effluent contained 100 and the B filter effluent 140,000 microbes per c.c.

SUMMARY AND CONCLUSIONS.

Summary and Conclusions.

In the first place it is desirable to recapitulate very briefly the chief conditions of experiments.

Two filters (A and B) alike in size, and containing similar material were dosed with liquid in the same way, the only difference being in the quality of the liquid treated. The filters were very small and for this reason (besides others) the experimental errors were no doubt considerable, so that the results can only be accepted in a very broad and general way. As previously explained, the experiments were intended, primarily, merely as a guide to the carrying out of experiments on a much larger scale and under modified and greatly improved conditions of experiment. From time to time during the course of the experiments many minor modifications in the process of treatment were introduced with the object of obtaining better purification. These are described in the text and they need not be repeated here.

It may be desirable, however, to give a table showing the kind of liquid treated by the two filters during the course of the experiments.

Date.	A Filter.	B Filter.
1903. Jan. 18th -	Filter and apparatus sterilised.	Filter and apparatus sterilised.
	1st SERIES OF EXPERIMENTS.	
Jan. 19th to May 29th.	A filter treats "heated" sewage (*i.e.*, sewage previously heated so as to kill all bacteria other than those present in the form of spores).	B filter treats "unheated" sewage.
	2nd SERIES OF EXPERIMENTS.	
May 29th to June 23rd.	A filter now treats "unheated" sewage.	B filter now treats "heated" sewage.
	3rd SERIES OF EXPERIMENTS.	
June 24th to July 15th.	A filter now receives sterile sodium chloride solution (0·5 per cent.).	B filter still treats "heated" sewage.
	4th SERIES OF EXPERIMENTS.	
July 16th to July 30th.	A filter again treats "unheated sewage" as in the second series of experiments.	B filter stills treats "heated" sewage.
	5th SERIES OF EXPERIMENTS.	
July 31st to Aug. 10th.	A filter still treats "unheated" sewage.	B filter treats completely sterilised sewage.
	6th SERIES OF EXPERIMENTS.	
Aug. 12th to Sept. 1st.	A filter treats dilute sterile urine (1 per cent.).	B filter still treats completely sterilised sewage.
	7th SERIES OF EXPERIMENTS.	
Sept. 2nd to Dec. 29th.	A filter treats a sterile artificial urea mixture.	B filter still treats completely sterilised sewage.

Summary and Conclusions.

1st SERIES OF EXPERIMENTS.

A filter treats "heated" sewage; B filter treats "unheated" sewage.

January 19th to May 29th, 1903.

The heating of the sewage may not have been uniformly quite satisfactory, and the possibility of accidental infection of the A filter from this cause or from the ingress of dust cannot be entirely excluded. Making every allowance, however, for imperfections in the conditions of experiment, the results seem to show that sporing bacteria can purify sewage to a certain extent.

Chemical Results.

Oxygen absorbed from Permanganate Test.—At first both filters purified the sewage to about the same extent. Later, owing to the presence of nitrites, the A filter effluent absorbed more oxygen from permanganate.

Free Ammonia.—The A filter effluent contained more free ammonia than the B filter effluent.

Albuminoid Ammonia.—Purification as judged by this test was not widely different in the two cases.

Nitrites.—At first neither effluent contained nitrites; later the B filter formed nitrites, which largely disappeared in favour of nitrates. On the other hand, the A filter produced a relatively large amount of nitrite but no nitrate. It is difficult to understand the nitrite production in the case of the A filter if the heating was as uniformly successful as the B. coli results seem to indicate. Possibly nitroso-bacteria gained entrance into the filter from the air and found the conditions suitable for multiplication. But why the nitrate producing bacteria did not also establish themselves is difficult to understand. It is conceivable, however, that if the experiment had been continued still longer nitrates might have appeared in the A filter effluent. But in this connection it should be noted that from April 20th to May 29th the A filter effluent produced nitrites in conspicuous amount, and if this was merely preparatory to nitrate formation the delay in its production was inexplicably long.

Nitrates.—At first neither filter effluent contained any nitrate; later the B filter alone produced nitrates.

Bacteriological.

Total Number of Bacteria.—It is remarkable that the A filter effluent usually contained many more bacteria than the B filter effluent.*

B. coli.—Practically speaking, it may be said that the A filter effluent contained no B. coli, whereas the B filter effluent contained B. coli in abundance.

B. enteritidis sporogenes.—As was to be anticipated the spores of this anærobe were present in both effluents.

Nitroso-bacteria.—The results were very variable, but the B filter yielded the highest results,

2nd SERIES OF EXPERIMENTS.

A filter now treats "unheated" sewage; B filter now treats "heated" sewage.

May 29th to June 23rd, 1903.

Chemical Results.

Oxygen absorbed from Permanganate.—Making fair allowance for the reducing action of nitrites, the purification effected by the A filter was not greatly inferior to that brought about by the B filter.

Free Ammonia.—The difference in the two filter effluents was not great as judged by this test.

Albuminoid Ammonia.—Both filters purified the sewage to about the same extent.

Nitrites.—The A filter effluent changed from a liquid containing nitrites but no nitrates to a liquid containing nitrates but hardly any nitrites. The B filter, on the other hand, remained practically unaffected and still produced nitrates and only traces of nitrites.

Nitrates.—The A filter produced nitrates; the B filter effluent contained nitrates as previously.

Bacteriological Results.

Total Number of Bacteria.—The results were variable and sometimes the A and sometimes the B filter claimed supremacy as regards total number of bacteria in the respective effluents.

B. coli.—The A filter effluent now contained B. coli in abundance, whereas the B filter effluent soon ceased to contain practically any B. coli, a circumstance which favours the view that B. coli and allied organisms have no necessary or direct concern in sewage purification processes. Further, the results suggest that if B. coli could not maintain its existence in a coli-infected filter it is most unlikely that B. typhosus would persist under parallel conditions.† This result is of importance from the epidemiological point of view.

B. enteritidis sporogenes.—As was to be expected, both filter effluents contained the spores of this anærobe.

Nitroso-bacteria.—The results were variable, but the B filter yielded the highest results.

3rd SERIES OF EXPERIMENTS.

A filter now receives sterile sodium chloride solution; B filter continues to treat "heated" sewage.

June 24th to July 15th, 1903.

Chemical Results.

Oxygen absorbed from Permanganate.—As regards the A filter, the effluent contained a good deal of oxidisable matter during the first two or three days, then the amount showed a decrease, but later an increase took place, and that was associated with the appearance of distinct turbidity. Even at the close of the experiment the effluent absorbed a considerable amount of oxygen from permanganate. The B filter continued to purify the "heated" sewage, the purification effected being 62 per cent.

Free and Albuminoid Ammonia.—Even at the end of the experiment the A filter contained a fair amount of free and albuminoid ammonia. As in the permanganate experiments, there was a period where the results were specially bad owing seemingly to a breaking down and washing out of the organic material previously stored in the filter. The B filter effected a 57 per cent. reduction of the albuminoid ammonia in the heated sewage.

Nitrites and Nitrates.—Throughout the experiments the effluent from the A filter yielded faint traces of nitrite and appreciable traces of nitrate. Presumably the nitrifying bacteria persisted in the filter and continued to oxidise the organic matter which had accumulated on the surfaces of the coke particles. The B filter continued to oxidise the "heated" sewage, the effluent containing traces only of nitrite and an appreciable amount of nitrate.

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* Comparable results have since been obtained at Lincoln and Guildford, but in these cases the liquid was treated before filtration with germicidal agents instead of by heat.

† These results are again, by inference, in conformity with the experience gained at Lincoln and Guildford.

Summary and Conclusions.

BACTERIOLOGICAL RESULTS.

Total Number of Bacteria.—The A filter continued to yield bacteria in great number, and the number was greatest at (or about) the time when the effluent became turbid in appearance. The effluent from the B filter contained a very large number of bacteria despite the fact of its treating sewage containing no microbes other than those present in the form of spores.

B. coli.—The effluents from both filters contained practically no B. coli, although previously this microbe was present in great numbers in both filters, and although the total number of bacteria still remained in each case very high. This again points to B. coli being an intruder and not necessarily concerned in the work of sewage purification. It suggests also that B. typhosus would be most unlikely to multiply in a sewage filter.

B. enteritidis sporogenes.—A few spores of this anærobe were found in both effluents.

Nitroso-bacteria.—The A filter effluent contained practically none, and the B filter a large number of these bacteria.

4th SERIES OF EXPERIMENTS.

A *filter now treats "unheated" sewage*; B *filter still treats "heated" sewage.*

July 16*th to July* 30*th*, 1903.

CHEMICAL RESULTS.

Oxygen absorbed from Permanganate.—Despite its previous dosing with sterile salt solution, the A filter was able to produce, even at the outset, a fair degree of purification of the "unheated" sewage. The average percentage purification was 62 as regards the A filter, and 71 in respect of the B filter.

Free and Albuminoid Ammonia.—The percentage reduction of albuminoid ammonia was 54 (A filter) and 51 (B filter).

Nitrites and Nitrates.—Both effluents contained traces of nitr*i*te. The A filter effluent contained only traces of nitr*a*te at first, but later an appreciable amount of nitr*a*te was produced. The B filter continued to oxidise the "heated" sewage.

BACTERIOLOGICAL RESULTS.

Total Number of Bacteria.—The A filter effluent contained fewer microbes than the B filter effluent.

B. coli test.—The A filter effluent now contained numerous B. coli; the B filter affluent none.

B. enteritidis sporogenes.—Both filters contained a few spores of this anærobe.

Nitroso-bacteria.—The B filter yielded the highest results.

5th SERIES OF EXPERIMENTS.

A *filter still treats "unheated" sewage*; B *filter now treats "completely sterilised" sewage.*

July 31*st to August* 10*th*, 1903.

CHEMICAL RESULTS.

Oxygen absorbed from Permanganate.—As judged by this test, both filters produced about the same percentage degree of purification.

Nitrites and Nitrates.—Both filter effluents contained nitr*a*tes, but traces only of nitr*i*tes.

No bacteriological analyses were made.

6th SERIES OF EXPERIMENTS.

A *filter treats sterile dilute urine (1 per cent.)*; B *filter still treats "completely sterilised" sewage.*

August 12*th to September* 1*st*, 1903.

CHEMICAL RESULTS.

Oxygen absorbed from Permanganate.—The A filter absorbed on an average 0·36 part of oxygen per 100,000 parts. The percentage purification in the case of the B filter was 62 per cent.

Free and Albuminoid Ammonia.—The A filter effluent contained on an average 3·12 and ·121 parts per 100,000 of free and albuminoid ammonia respectively. The percentage reduction of albuminoid ammonia in the case of the B filter was 51.

Nitrites and Nitrates.—At first both filter effluents contained nitr*i*tes, but later on these almost entirely disappeared. Both filters produced nitrates.

No bacteriological analyses were made.

7th SERIES OF EXPERIMENTS.

A *filter treats a sterile artificial urea mixture*; B *filter still treats "completely sterilised" sewage.*

September 2*nd to December* 29*th*, 1903.

CHEMICAL RESULTS.

Oxygen absorbed from Permanganate.—The percentage purification effected by the B filter was 62.

Free and Albuminoid Ammonia.—The percentage purification, as regards albuminoid ammonia, effected by the B filter was 41.

Nitrites and Nitrates.—Both effluents contained traces of nitr*i*tes and an appreciable amount of nitr*a*te.

BACTERIOLOGICAL RESULTS.

Only one sample was examined.

Total number of bacteria.—The A filter effluent contained 100 and the B filter effluent 140,000 microbes per c.c.

B. coli.—Neither effluent contained B. coli in 1 c.c.

B. enteritidis sporogenes.—The results in each case were negative.

A AND B FILTERS CONSIDERED SEPARATELY.

Summary and Conclusions.

It may assist the reader if the results obtained with the A and B filters are now considered separately.

A Filter.

Series I.—A sterile filter, treated with sewage previously heated so as to kill all but the spores of bacteria, purified the liquid to an appreciable extent. No nitrates were formed, but the production of nitr*i*tes was after a time well marked. These results require confirmation under conditions precluding the possibility of a casual infection or occasional under-heating of the sewage. The filter effluent contained practically no B. coli, but a larger number of bacteria than the effluent from a similar filter dealing with unheated sewage. Yet, of the two liquids, the latter (unheated sewage) must have contained initially at least 1,000 times as many bacteria as the former (heated sewage).

Series II.—When this filter (partially matured under what may be called unnatural conditions) received normal unheated sewage, the nitr*i*tes disappeared from the effluent and nitr*a*tes became evident. The bacteria necessary for complete oxidation can therefore seemingly assert their independence and exercise their functional activity even in a filter concurrently teeming with sporing bacteria. The bacterial flora of the effluent resembled that of an ordinary sewage effluent, and it therefore contained a large number of B. coli.

Series III.—When this filter (partially matured under unnatural conditions and then fully matured under natural conditions) was dosed with sterile sodium chloride solution, an effluent was produced such as might have resulted from the treatment of a *very* weak sewage. An interesting stage occurred during which the results were, relatively speaking, specially unsatisfactory, due seemingly to a sort of breaking up process in the interior of the filter. Since the aggregate amount of oxidised and unoxidised organic matter appearing in the effluent was considerable, it follows that the filter must have held in store a large amount of unoxidised organic matter. Although the effluent contained a large number of bacteria it is significant that B. coli was practically absent despite its previous prevalence in the filter. This is an important point, and indicates that conditions which are favourable to the multiplication of bacteria in general are not necessarily favourable to the development of particular bacteria, *e.g.*, B. coli.

Series IV. and V.—When this filter (partially matured under unnatural conditions, then fully matured under natural conditions, and subsequently dosed with sterile sodium chloride solution for a considerable time) was called upon again to treat unheated sewage it was observed that *even at the outset* it was able to purify the sewage to a very appreciable extent. The prolonged working with sterile sodium chloride solution had thus apparently failed to rob the filter of its purifying ability. The bacterial flora of the effluent again resembled that of an ordinary sewage effluent, in that it contained a large number of B. coli.

Series VI.—When this filter (partially matured under unnatural conditions, then fully matured under natural conditions, next dosed with sterile sodium chloride solution, and lastly again fully matured under normal conditions) was called upon to treat sterile dilute urine it was able to manufacture nitr*a*tes apparently without any difficulty. The fact of the urine being sterile appeared to be of no importance in view of the mature condition of the filter; and Mr. Frye's experiments at Leeds, Mr. Hendrick's and (subsequently) Dr. McGowan's experiments with pot ale, and the joint experiments at Guildford and elsewhere by Dr. McGowan and myself, all seem to support the view that when once a filter is mature it can purify oxidisable matter without the accompanying addition of bacteria in the liquid being treated, probably indefinitely. It thus appears that once a filter is mature (bacteriologically) it is independent of the presence of *fresh* bacteria to maintain its state of maturity. Indeed, it is probable that even during the process of maturing a sewage filter the vast majority of the excremental bacteria in the sewage are merely intruders. It may be supposed that the bacteria necessary for the purification of sewage gradually gain a foothold in the filter taking up their quarters, as it were, for permanent residence and multiplication. Meanwhile the vast majority of the bacterial population of sewage constantly pass away with the effluent. Some, no doubt, are mechanically arrested only to be washed out subsequently or to suffer extinction under conditions unfavourable to their sustained vitality. Other bacteria perhaps are able to maintain their existence indefinitely in the filter, although serving no good purpose in the work of purification. However this may be, it seems clear that once an appropriate bacterial flora has been established in a filter, it is no longer necessary that the liquid to be purified should carry with it any bacteria.

Series VII.—When this filter (partially matured under unnatural conditions, then fully matured under natural conditions, next dosed with sterile sodium chloride solution, then fully matured under normal conditions, and lastly dosed with sterile dilute urine) was called upon to treat a sterile artificial urea mixture a fair amount of nitrate was produced. The effluent contained no B. coli. The final experiment lasted nearly four months.

B Filter.

Series I.—A sterile filter treated with unheated sewage purified the liquid in the ordinary way. First nitr*i*tes appeared in the effluent and then nitr*a*tes, the appearance of the latter being followed by the disappearance, relatively speaking, of the former. The effluent of course contained B coli. in great abundance.

Series II., III. and IV.—When this filter (matured under normal conditions) was called upon to treat sewage previously heated so as to kill all but the spores of bacteria, it continued to oxidise the liquid as previously. The effluent contained more bacteria but no B coli.

Series V., VI. and VII.—When this filter (matured under normal conditions and then dosed with "heated" sewage) was called upon to treat completely sterilised sewage it continued to oxidise the liquid as before. The effluent (series VI.) contained a great many bacteria but no B coli.

We have here then additional evidence that a *mature* filter can continue to oxidise organic matter independently of bacteria in the liquid being treated. Further, the evidence is conclusive that although a filter may contain initially an enormous number of B. coli, when the liquid to be treated is bereft of B. coli, this microbe rapidly disappears from the effluent although the filter may still be able to support the life of many other bacteria.

Inferentially, it may be concluded that sewage filters are not likely to provide suitable breeding grounds for pathogenic bacteria, although I think they offer no certain obstacle to the passage through them of these microbes.

It may be premature to generalise on this subject, but so far as my experience goes, the same is true of water filters. For example, a certain small proportion of the B. coli in unfiltered water constantly escapes the barrier of the filter beds, but there is no evidence to show, rather the reverse, that in passing through the sand or under-drains they undergo multiplication. Under certain abnormal conditions which need not be described here, the effluent from a sand filter may contain actually more bacteria than the water before filtration. This may be due to an abnormal detachment of microbes normally chained, as it were, to the sand particles, or to a great multiplication of bacteria in the interstices of the sand or in the under-drains, owing to the creation of some new condition favourable to their vitality, or to a combination of these or other causes. But, in my experience, the B. coli do not share proportionately, if at all, in this multiplication. In other words, when, from one or another cause, the conditions favour multiplication within a filter, the B. coli do not apparently take advantage of this circumstance. It follows that, although pathogenic bacteria may be able to pass through filter beds, it is unlikely that they are able to multiply therein.

A. C. HOUSTON.

RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF SAMPLES OF SEWAGE AND EFFLUENTS FROM THE BRADFORD, ILFORD, LEEDS, AND MANCHESTER SEWAGE WORKS, BY DR. A. C. HOUSTON.

BRADFORD

Results of the Bacteriological Examination of samples as under:—

FRIZINGHALL WORKS—

CRUDE SEWAGE.

TANK LIQUOR (SEWAGE AFTER TREATMENT WITH SULPHURIC ACID AND SETTLEMENT).

EFFLUENTS FROM VARIOUS FILTERS.

NORTH BIERLEY OUTFALL WORKS—

EFFLUENTS FROM VARIOUS FILTERS (THE SEWAGE IS TREATED WITH ALUMINO-FERRIC AND LIME, ALLOWED TO SETTLE, AND THEN PASSED ON TO THE FILTERS).

SMALL STREAM BELOW EFFLUENT DISCHARGE CHANNEL.

IDLE OUTFALL WORKS—

EFFLUENTS FROM "LAND FILTERS" (THE SEWAGE IS TREATED WITH ALUMINO-FERRIC AND DISCHARGED WITHOUT SETTLEMENT ON TO "LAND FILTERS").

ALL THE SAMPLES WERE COLLECTED FROM THE MAIN EFFLUENT CHANNEL DISCHARGING TO THE RIVER.

SUMMARY OF CONTENTS—

A. C. HOUSTON.

BRADFORD.

Results of the Bacteriological Examination of Samples from (1) Frizinghall

1						2		3						4			
Description of the Sample.						Total Number of Bacteria in 1 c.c.		Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method).						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection.				Other Details.									Gas.	Indol.	(a) Acidity. (b) Clot.	
	Hour.	Day.	Month.	Year.		Gelatine at 20° C.	Agar at 37° C.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	(Gelatine "shake" cultures, 24 hrs. at 20° C.)	(Broth cultures, 5 days at 37° C.)	(Litmus milk cultures, 5 days at 37° C.) (a)	(b)
1	—	11	3	1902	Frizinghall Crude Sewage (48 half-hourly samples)												
2	—	30	10	"	Frizinghall Crude Sewage	70,000,000	12,000,000										
.. ..	—	6	11	"	Frizinghall Crude Sewage	[illegible]6,800,000	9,840,000										
4	—	12	"	"	Frizinghall Crude Sewage	57,600,000	10,720,000										
5	—	19	"	"	Frizinghall Crude Sewage	39,400,000	4,600,000										
6	—	26	"	"	Frizinghall Crude Sewage												
7	—	3	12	"	Frizinghall Crude Sewage		540,000										
8	—	10	12	"	Frizinghall Crude Sewage							+	—	+	—	+	—
9	—	18	12	"	Frizinghall Crude Sewage ..												
10	—	31	"	"	Frizinghall Crude Sewage ..		6,290,000										
11	—	7	1	1903	Frizinghall Crude Sewage ..								+	+	+	+	+
12	—	14	"	"	Frizinghall Crude Sewage ..												
13	—	21	"	"	Frizinghall Crude Sewage ..		2,610,000										
14	—	28	"	"	Frizinghall Crude Sewage								+	+	+	+	+
15	—	4	2	"	Frizinghall Crude Sewage ..												
16	—	11	2	"	Frizinghall Crude Sewage ..		5,940,000										
17	—	18	"	"	Frizinghall Crude Sewage ..								+	+	+	+	+
18	—	25	"	"	Frizinghall Crude Sewage ..												
19	—	4	3	"	Frizinghall Crude Sewage		560,000										
20	—	11	"	"	Frizinghall Crude Sewage												
21	—	18	"	"	Frizinghall Crude Sewage								+	+	—	+	—
22	—	25	"	"	Frizinghall Crude Sewage		3,500,000										
23	—	1	4	"	Frizinghall Crude Sewage												
24	—	11	3	1902	Frizinghall Sewage (48 half-hourly samples) after sulphuric acid treatment												
25	—	2	7	"	Frizinghall Tank Liquor (Sewage after treatment with sulphuric acid, and settlement)		2,200										
26	—	30	10	"	Frizinghall Tank Liquor (Sewage after treatment with sulphuric acid and settlement)	160,000	120,000										
27	—	6	11	"	Frizinghall Tank Liquor (Sewage after treatment with sulphuric acid and settlement)	44,000,000	7,360,000										

BRADFORD.

WORKS; (2) NORTH BIERLEY OUTFALL WORKS; AND (3) IDLE OUTFALL WORKS.

5						6						7						8	
Indol Test. Indol in broth cultures direct (5 days at 37° C.).						B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						B.S.=Bile-salt Glucose Peptone Test. N.R.=Neutral-red Broth Test. L.P.M.=Lactose Peptone Milk Test.						No.	REMARKS.
1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000		
1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.		
									+	—						L.P.M. +	N.R. B.S. +	1	
								+	—								B.S. +	2	
								+	—								B.S. +	3	
								+	—								B.S. +	4	
								+	—								B.S. +	5	
									+	—							B.S. +	6	
									+	—								7	
								+	—									8	
								+	—								B.S. +	9	
							+	—										10	
					+			+	—									11	
									+	—							B.S. +	12	
								+	—									13	
					+				+									14	
								+	—								B.S. +	15	
									+	—								16	
					+			+	—									17	Virulent B. pyocyaneus isolated from this sample.
									+	—						B.S. +	—	18	
								+	—									19	
									+	—							B.S. +	20	
					+		+	—										21	
								+	—									22	
									+	—							B.S. +	23	
									+	—							N.R. B.S. +	24	
			+	—														25	
							+	—								B.S. +	—	26	
									+	—							B.S +	27	

Results of the Bacteriological Examination of Samples from (1) Frizinghall

No.	Time of Collection. Hour.	Day.	Month.	Year.	Other Details.	Total Number of Bacteria in 1 c.c. Gelatine at 20° C.	Agar at 37° C.	Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method). 1 (1 c.c.)	10 (·1 c.c.)	100 (·01 c.c.)	1,000 (·001 c.c.)	10,000 (·0001 c.c.)	100,000 (·00001 c.c.)	Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3. Gas. (Gelatine "shake" cultures, 24 hrs. at 20° C.)	Indol. (Broth cultures, 5 days at 37° C.)	(a) Acidity. (b) Clot. (Litmus milk cultures, 5 days at 37° C.) (a)	(b)
1						2		3						4			
28	—	12	11	1902	Frizinghall Tank Liquor (Sewage after treatment with sulphuric acid and settlement)	1,580,000	1,590,000										
29	—	19	,,	,,	Frizinghall Tank Liquor (Sewage after treatment with sulphuric acid and settlement)	5,600,000	630,000										
30	—	26	,,	,,	Frizinghall Tank Liquor (Sewage after treatment with sulphuric acid and settlement)												
31	—	3	12	,,	Frizinghall Tank Liquor (Sewage after treatment with sulphuric acid and settlement)		1,090,000										
32	—	10	,,	,,	Frizinghall Tank Liquor (Sewage after treatment with sulphuric acid and settlement)								+	+	—	+	—
33	—	18	,,	,,	Frizinghall Tank Liquor (Sewage after treatment with sulphuric acid and settlement)												
34	—	31	,,	,,	Frizinghall Tank Liquor (Sewage after treatment with sulphuric acid and settlement)		5,000										
35	—	7	1	1903	Frizinghall Tank Liquor (Sewage after treatment with sulphuric acid and settlement)					+	—			+	+	+	
36	—	14	,,	,,	Frizinghall Tank Liquor (Sewage after treatment with sulphuric acid and settlement)												
37	—	21	,,	,,	Frizinghall Tank Liquor (Sewage after treatment with sulphuric acid and settlement)		400										
38	—	28	,,	,,	Frizinghall Tank Liquor (Sewage after treatment with sulphuric acid and settlement)					+	—			+	+	+	+
39	—	4	2	,,	Frizinghall Tank Liquor (Sewage after treatment with sulphuric acid and settlement)												
40	—	11	,,	,,	Frizinghall Tank Liquor (Sewage after treatment with sulphuric acid and settlement)		37,000										
41	—	18	,,	,,	Frizinghall Tank Liquor (Sewage after treatment with sulphuric acid and Settlement)						+	—		+	+	+	+
42	—	25	,,	,,	Frizinghall Tank Liquor (Sewage after treatment with sulphuric acid and settlement)												
43	—	4	3	,,	Frizinghall Tank Liquor (Sewage after treatment with sulphuric acid and settlement)		10,000										
44	—	11	,,	,,	Frizinghall Tank Liquor (Sewage after treatment with sulphuric acid and settlement)												
45	—	18	,,	,,	Frizinghall Tank Liquor (Sewage after treatment with sulphuric acid and settlement)					+	—			+	+	+	—
46	—	25	,,	,,	Frizinghall Tank Liquor (Sewage after treatment with sulphuric acid and settlement)		34,000										
47	—	1	4	,,	Frizinghall Tank Liquor (Sewage after treatment with sulphuric acid and settlement)												
48	—	14	4	1904	Frizinghall Tank Liquor (Sewage after treatment with sulphuric acid and settlement)								+	+	+	+	+
49	—	28	5	1902	Frizinghall Effluent from Filter No. 1c.	550,000	87,000						+	+	—	+	—
50	—	12	6	,,	Frizinghall Effluent from Filter No. 1c.	5,520,000	891,000			+	—			+	+	+	+
51	—	20	,,	,,	Frizinghall Effluent from Filter No 1c.	3,360,900	25,000	+	—					+	+	+	+
52	—	2	7	,,	Frizinghall Effluent from Filter No. 1c.		250,000										
53	—	9	,,	,,	Frizinghall Effluent from Filter No. 1c.		90,000										

Works; (2) North Bierley Outfall Works; and (3) Idle Outfall Works—*continued.*

5						6						7						8	
Indol Test. Indol in broth cultures direct (5 days at 37° C.).						B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						B.S.=Bile-salt Glucose Peptone Test. N.R.=Neutral-red Broth Test. L.P.M.=Lactose Peptone Milk Test.						No.	REMARKS.
1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000		
1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.		
							+	–									B.S. +	28	
							+	–									B.S. +	29	
							+	–									B.S. +	30	
								+	–									31	
				+	–		+	–										32	
							+	–							B.S. +	–		33	
						+	–											34	
		+	–				+											35	
							+	–						B.S. –				36	
							+	–										37	
		+	–				+	–										38	
							+	–						B.S. –				39	
							+	–										40	
			+	–		+	–											41	
							+	–						B.S. +	–			42	
							+	–										43	
							+	–						B.S. –				44	
		+	–			+	–											45	
								+	–									46	
							+	–						B.S. –				47	
							+	–									N.R. +	48	
				+	–													49	
			+	–														50	
	+	–																51	
		+	–															52	
							+											53	

Results of the Bacteriological Examination of Samples from (1) Frizingha

1						2		3						4			
Description of the Sample.						Total Number of Bacteria in 1 c.c.		Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method).						Chief Biological Characters of the *strain* of B. Coli pres nt i the number spec fied in Col. 3.			
No.	Time of Collection.				Other Details.									Gas.	Indol.	(a) Acidity. (b) Clot. (Litmus milk cultures, 5 days at 37° C.)	
	Hour.	Day.	Month.	Year.		Gelatine at 20° C.	Agar at 37° C.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	(Gelatine "shake" cultures, 24 hrs. at 20° C.)	(Broth cultures, 5 days at 37° C.)	(a)	(b)
54	—	16	7	1902	Frizinghall Effluent from Filter No. 10.		1,300										
55	—	24	7	„	Frizinghall Effluent from Filter No. 10		1,590										
56	—	30	7	„	Frizinghall Effluent from Filter No. 10		1,760,000										
57	—	6	8	„	Frizinghall Effluent from Filter No. 10		7,200										
58	—	13	8	„	Frizinghall Effluent from Filter No. 10		40,000										
.. ..	—	20	8	„	Frizinghall ˉ ffluent from Filter No. 10		5,000										
60	—	„	9	„	Frizinghall Effluent from Filter No. 10		38,000										
61	—	9	„	„	Frizinghall Effluent from Filter No. 10	5,200,000	310,000										
62	—	17	9	„	Frizinghall Effluent from Filter No. 10	290,000	11,000										
63	—	1	10	„	Frizinghall Effluent from Filter No. 10	5,100,000	440,000										
64	—	8	10	„	Frizinghall Effluent from Filter No. 10	3,600,000	220,000										
65	—	15	10	„	Frizinghall Effluent from Filter N . 10	370,000	59,000										
66	—	23	„	„	Frizinghall Effluent from Filter No. 10	90,000	6,000										
67	—	30	„	„	Frizinghall Effluent from Filter No. 10	230,000	7,300							–			
68	—	12	11	„	Frizinghall Effluent from Filter No. 10	8,300,000	1,310,000										
69	—	19	11	„	Frizinghall Effluent from Filter No. 10	7,000,000	2,800,000										
70	—	26	11	„	Frizinghall Effluent from Filter No. 10												
71	—	3	12	„	Frizinhall Effluent from Filter No. 10		54,000										
72	—	10	12	„	Frizinhall Effluent from Filter No. 10							+	—	+	—	+	—
73	—	18	„	„	Frizinghall Effluent from Filter No. 10												
74	—	31	12	„	Frizinghall Effluent from Filter No. 10		2,600										
75	—	7	1	1903	Frizinghall Effluent from Filter No. 10					+	—			+	+	+	+
76	—	14	1	„	Frizinghall Effluent from Filter No. 10												
77	—	21	1	„	Frizinghall Effluent from Filter No. 10		600										
78	—	28	1	„	Frizinghall Effluent from Filter No. 10					+	—			+	+	+	+
79	—	4	2	„	Frizinghall Effluent from Filter No. 10												
80	—	11	„	„	Frizinghall Effluent from Filter No. 10		15,000										
81	—	18	2	„	Frizinghall Effluent from Filter No. 1					+	—			+	+	+	+
82	—	25	2	„	Frizinghall Effluent from Filter No. 10												
83	—	4	3	„	Frizinghall Effluent from Filter No. 10		700										
84	—	11	3	„	Frizinghall Effluent from Filter No. 10												
85	—	18	3	„	Frizinghall Effluent from Filter No. 10					—							

Works; (2) North Bierley Outfall Works; and (3) Idle Outfall Works—*continued.*

5						6						7						8	
Indol Test. Indol in broth cultures direct (5 days at 37° C.).						B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						B.S.=Bile-salt Glucose Peptone Test. N.R.=Neutral-red Broth Test. L.P.M.=Lactose Peptone Milk Test.						No.	REMARKS.
1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000		
1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.		
						+	—											54	
							+	—										55	
								+	—									56	
							+	—					B.S. +	—				57	
						—						B.S. +	—					58	
							+	—				B.S. +	—					59	
						+	—							B.S. +	—			60	
								+	—						B.S. +	—		61	
							+	—										62	
						+	—										B.S. +	63	
							+	—									B.S +	64	
						+	—										B.S. +	65	
						+	—							B.S. +	—			66	
							+	—						B.S. +	—			67	
							+	—									B.S. +	68	
						+	—										B.S. +	69	
								+	—								B.S. +	70	
							+	—										71	
				+	—	+	—											72	
						+	—								B.S. +	—		73	
						+	—											74	
		+	—				+	—										75	
								+	—					B.S. +	—			76	
						+	—											77	
		+	—					+	—									78	
								+	—					B.S. +	—			79	
							+	—										80	
		+	—			+	—											81	
							+	—						B.S. —				82	
						+	—											83	
							+	—						B.S. +	—			84	
		—				+	—											85	

Results or the Bacteriological Examination of Samples from (1) Frizinghall

1						2		3						4			
No.	Description of the Sample. Time of Collection. Hour.	Day.	Month.	Year.	Other Details.	Total Number of Bacteria in 1 c.c. Gelatine at 20° C.	Agar at 37° C.	Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method). 1 — 1 c.c.	10 — ·1 c.c.	100 — ·01 c.c.	1,000 — ·001 c.c.	10,000 — ·0001 c.c.	100,000 — ·00001 c.c.	Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3. Gas. (Gelatine "shake" cultures, 24 hrs. at 20° C.)	Indol. (Broth cultures, 5 days at 37° C.)	(*a*) Acidity. (*b*) Clot. (Litmus milk cultures, 5 days at 37° C.) (*a*)	(*b*)
.. ..	—	25	3	1903	Frizinghall Effluent from Filter No. 1c		26,000										
.. ..	—	1	4	"	Frizinghall Effluent from Filter No. 1c												
88	—	28	5	1902	Frizinghall Effluent from Filter No. 2c	850,000	81,000				+			+	+	+	+
89	—	5	6	"	Frizinghall Effluent from Filter No. 2c	81,000	10,000			+	—			+	+	+	+
90	-	12	"	"	Frizinghall Effluent from Filter No. 2c		1,106,000			+	—			+	+	+	+
91	—	20	6	"	Frizinghall Effluent from Filter No. 2c	112,000	13,000	+	—					+	+	+	+
92	—	2	7	"	Frizinghall Effluent from Filter No. 2c		280,000										
93	—	9	"	"	Frizinghall Effluent from Filter No. 2c		25,000										
94	—	16	"	"	Frizinghall Effluent from Filter No. 2c		10,000										
95	—	24	"	"	Frizinghall Effluent from Filter No. 2c		90,000										
96	—	30	"	"	Frizinghall Effluent from Filter No. 2c		44,000										
97	—	6	8	"	Frizinghall Effluent from Filter No. 2c		5,100										
98	—	13	"	"	Frizinghall Effluent from Filter No. 2c		20,000										
99	—	20	"	"	Frizinghall Effluent from Filter No. 2c		140,000										
100.. ..	—	9	9	"	Frizinghall Effluent from Filter No. 2c	2,200,000	2[illegible]0,000										
101.. ..	—	17	"	"	Frizinghall Effluent from Filter No. 2c	7,900,000	33,000										
102.. ..	—	25	"	"	Frizinghall Effluent from Filter No. 2c	3,300,000	810,000										
103.. ..	—	15	10	"	Frizinghall Effluent from Filter No. 2c	3,800,000	480,000										
104	—	23	"	"	Frizinghall Effluent from Filter No. 2c	280,000	30,000										
105.. ..	—	30	"	"	Frizinghall Effluent from Filter No. 2c	157,000	5,700										
106	—	6	11	"	Frizinghall Effluent from Filter No. 2c	820,000	131,000										
107.. ..	—	12	"	"	Frizinghall Effluent from Filter No. 2c	1,600,000	159,000										
108.. ..	—	19	"	"	Frizinghall Effluent from Filter No. 2c	102,000	27,000										
109.. ..	—	26	"	"	Frizinghall Effluent from Filter No. 2c												
110.. ..	—	3	12	"	Frizinghall Effluent from Filter No. 2c		8,000										
111.. ..	—	10	"	"	Frizinghall Effluent from Filter No. 2c					+	—			+	—	+	—
112.. ..	—	18	"	"	Frizinghall Effluent from Filter No. 2c												
113.. ..	—	31	"	"	Frizinghall Effluent from Filter No. 2c		500										
114.. ..	—	7	1	1903	Frizinghall Effluent from Filter No. 2c					—							
115.. ..	—	14	"	"	Frizinghall Effluent from Filter No. 2c												
116.. ..	—	21	"	"	Frizinghall Effluent from Filter No. 2c		100										
117.. ..	—	28	"	"	Frizinghall Effluent from Filter No. 2c												

Works; (2) North Bierley Outfall Works; and (3) Idle Outfall Works—*continued.*

5						6						7						No.	REMARKS.
Indol Test. Indol in broth cultures direct (5 days at 37° C.).						B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						B.S.=Bile-salt Glucose Peptone Test. N.R.=Neutral-red Broth Test. L.P.M.=Lactose Peptone Milk Test.							
[illegible]	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000		
[illegible]	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.		
								+	—									86	
							+	—						B.S. —				87	
			+	—														88	
		+	—															89	
			+	--														90	
	—																	91	
			+	—														92	B. prodigiosus isolated from 1/100 c.c.
							+	—										93	
							+	—										94	
							+	—										95	
							+	—										96	
							+	—				B.S. +	—					97	
						+	—						B.S. +	—				98	
						+	—								B.S. +	—		99	
								+	—							B.S. +	—	100	
								+	—									101	
								+	—								B.S. +	102	
						+	—								B.S. +	—		103	
						—									B.S. +	—		104	
							+	—								B.S. +	—	105	
							+	—							B.S. +	—		106	
						+	--									B.S. +	—	107	
						—									B.S. +			108	
						+	—							B.S. +	—			109	
						+	—											110	
						+	—											111	
						+	—								B.S. +	—		112	
						+	—											113	
		—				—												114	
						+	—							B.S. --				115	
						+	—											116	
		—				+	—											117	

Results of the Bacteriological Examination of Samples from (1) Frizinghall

1						2		3						4			
Description of the Sample.						Total Number of Bacteria in 1 c.c.		Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method).						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection.				Other Details.									Gas.	Indol.	(a) Acidity (b) Clot.	
	Hour.	Day.	Month.	Year.		Gelatine at 20° C.	Agar at 37° C.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	(Gelatine "shake" cultures, 24 hrs. at 20° C.)	(Broth cultures, 5 days at 37° C.)	(Litmus milk cultures, 5 days at 37° C.) (a)	(b)
118.. ..	—	4	2	1903	Frizinghall Effluent from Filter No. 2C												
119.. ..	—	11	,,	,,	Frizinghall Effluent from Filter No. 2C		160										
120.. ..	—	18	,,	,,	Frizinghall Effluent from Filter No. 2C					+	—			+	+	+	+
121.. ..	—	25	,,	,,	Frizinghall Effluent from Filter No. 2C												
122.. ..	—	4	3	,,	Frizinghall Effluent from Filter No. 2C		60										
123.. ..	—	11	,,	,,	Frizinghall Effluent from Filter No. 2C												
124.. ..	—	18	,,	,,	Frizinghall Effluent from Filter No. 2C					+	—			+	+	+	+
125.. ..	—	25	3	,,	Frizinghall Effluent from Filter No. 2C		400										
126.. ..	—	1	4	,,	Frizinghall Effluent from Filter No. 2C												
127.. ..	—	30	7	1902	Frizinghall Effluent from Filter No. 3		1,780,000										
128.. ..	—	1	10	,,	Frizinghall Effluent from Filter No. 3	100,000,000	9,440,000										
129.. ..	—	5	6	1903	Effluent from N. Bierley, Filter No. 1N	1,800	160			+	—			+	—	+	+
130.. ..	—	,,	,,	,,	Effluent from N. Bierley, Filter No. 3N	250,000	94,000			+	—			+	—	+	—
131 .	—	20	,,	,,	Effluent from N. Bierley, Filter No. VI. N	7,700	640	—									
132.. ..	—	13	8	,,	Effluent from N. Bierley, Filter No. 1N		50,000										
133.. ..	—	1	9	,,	Effluent from N. Bierley Filter, No. IVN		260,000										
134.. ..	—	18	,,	,,	Effluent from N. Bierley Filter No. 1 N	270,000	33,000										
135.. ..	—	16	7	,,	N. Bierley. Small stream below Effluent discharge channel.		210,000										
136.. ..	—	24	,,	,,	N. Bierley. Small stream below Effluent discharge channel		100,000										
137.. ..	—	9	,,	,,	Idle Works Final Effluent ..		410,000										
138.. ..	—	7	8	,,	Idle Works Final Effluent												
139.. ..	—	20	,,	,,	Idle Works Final Effluent		57,000										
140.. ..	—	9	2	,,	Idle Works Final Effluent	1,150,000	120,000										
141.. ..	—	8	10	,,	Idle works Final Effluent - -	17,400,000	500,000										

Works; (2) North Bierley Outfall Works; and (3) Idle Outfall Works—*continued.*

5						6						7						8	
Indol Test. Indol in broth cultures direct (5 days at 37° C.).						B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anaerobic milk cultures). Cultures heated to 80° C. for 10 minutes.						B.S.=Bile-salt Glucose Peptone Test. N.R.=Neutral-red Broth Test. L.P.M.=Lactose Peptone Milk Test.						No.	REMARKS.
1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000		
1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.		
						+	—							B.S. —				118	
						+	—											119	
		+	—			+	—											120	
						—								B.S. —				121	
						—												122	
						+	—							B.S. —				123	
		+	—			—												124	
						+	—											125	
						+	—							B.S. —				126	
						+	—											127	
								+	—								B.S. +	128	
		+	—															129	As regards the North Bierley samples, it should be noted that the sewage is treated with alumino-ferric and lime, allowed to settle, and then passed on to the filters.
				+	—													130	
+	—																	131	
						—						B.S. +	—					132	
						+	—								B.S. +	—		133	
						—								B.S. +				134	
							+	—										135	
						+	—											136	
								+	—									137	As regards the Idle samples, these were collected from the main effluent channel discharging into the river, the crude sewage in this case being treated with alumino-ferric and discharged without settlement on to "Land Filters."
														B.S. +	—			138	
						+	—								B.S. +	—		139	
							+	—								B.S. +	—	140	
							+	—								B.S. +		141	

SUMMARY.*

Frizinghall Crude Sewage

Total Number of Bacteria (Gelatine at 20° C.) per c.c.

4 Samples.

Average number - - - - - -	58,450,000
Highest number - - - - - -	70,000,000
Lowest number - - - - - -	39,400,000

Total Number of Bacteria (Agar at 37° C.) per c.c.

10 Samples.

Average number - - - - - -	5,666,000
Highest number - - - - - -	12,000,000
Lowest number - - - - - -	540,000

B. Coli Test.

5 Samples.

One sample contained 10,000, the remaining four samples at least 100,000 B. coli (or coli-like microbes) per c.c.

As regards biological characters, two of the coli-like microbes were atypical: the remaining three microbes were, on the basis of the tests employed, typical B. coli.

Indol Test.

4 Samples.

All four samples yielded the same result, namely, at least 100,000 indol producing bacteria per c.c. (+ ·00001 c.c.).

Frizinghall Crude Sewage.

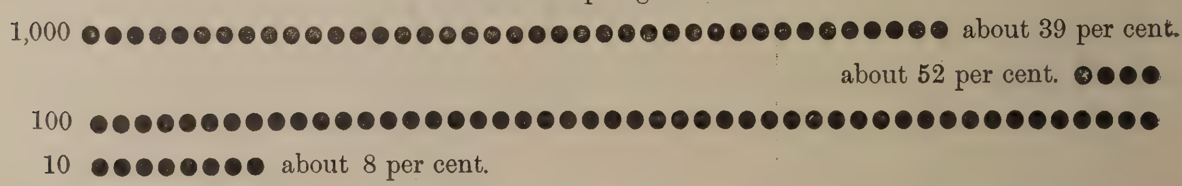
B. Enteritidis Sporogenes Test.

23 Samples.

9 samples	(about 39 per cent.)	1,000	(+ ·001 c.c.)
12 „	(about 52 per cent.)	100	(+ ·01 c.c.)
2 „	(about 8 per cent.)	10	(+ ·1 c.c.)

These results may be shown in the following diagram (each dot represents one per cent. of the samples) as follows:—

B. Enteritidis Sporogenes Test.



Bile-salt Glucose Peptone Test.

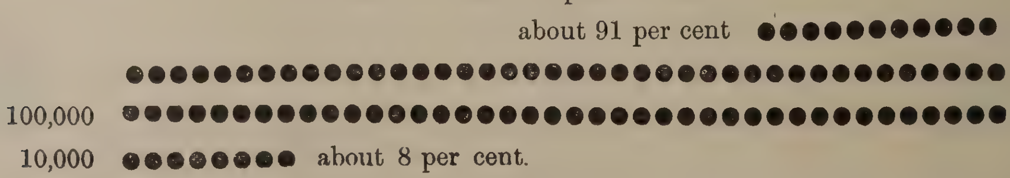
12 Samples.

11 samples (91 per cent.) at least 100,000 (+ ·00001 c.c.)

1 sample (8 per cent.) 10,000 (+ ·0001 c.c.)

These samples may be shown in the following diagram (each dot represents one per cent. of the samples) as follows:—

Bile-salt Glucose Peptone Test.



* Unless otherwise stated, the results are given as the number of bacteria per c.c. of sample.

N.B.—It should be noted that the B. coli, indol, and bile-salt glucose peptone tests were not "pushed" beyond $\frac{1}{100000}$ c.c.

Frizinghall Tank Liquor.

Total Number of Bacteria (Gelatine at 20° C.) per c.c.

4 Samples.

Average number - - - - - - -	12,835,000
Highest „ - - - - - - -	44,000,000
Lowest „ - - - - - - -	160,000

Total Number of Bacteria (Agar at 37° C.) per c.c.

11 Samples.

Average number - - - - - - -	988,963
Highest „ - - - - - - -	7,360,000
Lowest „ - - - - - - -	400

B. Coli Test.

6 Samples.

2 samples, 100,000 B. coli (or coli-like microbes) per c.c.
1 sample, 1,000 „ „ „ „
3 samples, 100 „ „ „ „

As regards biological characters, two of the coli-like microbes were atypical: the remaining four microbes were, on the basis of the tests employed, typical B. coli.

Indol Test.

6 Samples.

1 sample 10,000 indol producing bacteria (+ ·0001 c.c.)
2 samples 1,000 „ „ „ (+ ·001 c.c.)
3 „ 100 „ „ „ (+ ·01 c.c.).

Frizinghall Tank Liquor.

B. Enteritidis Sporogenes Test.

24 Samples.

2 samples (about 8 per cent.) 1,000 (+ ·001 c.c.)
2 samples (about 8 per cent.) 100 (+ ·01 c.c.)
17 samples (about 70 per cent.) 10 (+ ·1 c.c.)
3 samples (about 12 per cent.) 1 (+ 1 c.c.)

These results may be shown in the following diagram (each dot represents one per cent. of the samples) as follows:—

B. Enteritidis Sporogenes Test.

1,000 ●●●●●●●● about 8 per cent.
100 ●●●●●●●● about 8 per cent.
about 70 per cent. ●●●●●●●●●●●●●●●●●●●
10 ●●
1 ●●●●●●●●●●●● about 12 per cent.

Bile-salt Glucose Peptone Test.

12 Samples.

5 samples (about 41 per cent.) at least 100,000 (+ ·00001 c.c.)
1 sample (about 8 per cent.) 10,000 (+ ·0001 c.c.)
1 sample (about 8 per cent.) 1,000 (+ ·001 c.c.)
1 sample (about 8 per cent.) 100 (+ ·01 c.c.)
4 samples (about 33 per cent.) negative result $\frac{1}{100}$ c.c. (− ·01 c.c.)

These results may be shown in the following diagram (each dot represents one per cent. of the samples) as follows :—

Bile-salt Glucose Peptone Test.

about 41 per cent. ●●●●

100,000 ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●

10,000 ●●●●●●●● about 8 per cent.

1,000 ●●●●●●●● about 8 per cent.

100 ●●●●●●●● about 8 per cent.

About 33 per cent. negative $\frac{1}{100}$ c.c.

Frizinghall Effluent from Filter No. 1 C.

Total Number of Bacteria (Gelatine at 20° C.) per c.c.

12 Samples.

Average number - - - - - - -	3,300,000
Highest „ - - - - - - -	8,300,000
Lowest „ - - - - - - -	90,000

Total Number of Bacteria (Agar at 37° C.) per c.c.

27 Samples.

Average number - - - - - - -	311,000
Highest „ - - - - - - -	2,800,000
Lowest „ - - - - - - -	600

B. Coli Test.

8 Samples.

1 sample, 100,000 (+ ·00001 c.c.).
1 „ 10,000 (+ ·0001 c.c.).
4 samples, 100 (+ ·01 c.c.).
1 sample, 1 (+ 1 c.c.).
1 „ negative result $\frac{1}{100}$ c.c. (— ·01 c.c.)

Five out of the seven coli-like microbes isolated from the samples were, on the basis of the tests employed, typical B. coli.

Indol Test.

9 Samples.

2 samples, 10,000 (+ ·0001 c.c.).
1 sample, 1,000 (+ ·001 c.c.).
4 samples, 100 (+ ·01 c.c.).
1 sample, 10 (+ ·1 c.c.).
1 sample, negative result $\frac{1}{100}$ c.c. (— ·01 c.c.)

Frizinghall Effluent from Filter No. 1 C.

B. Enteritidis Sporogenes Test.

35 Samples.

7 samples (about 20 per cent.) 100 (+ ·01 c.c.)
14 samples (about 40 per cent.) 10 (+ ·1 c.c.)
13 samples (about 37 per cent.) 1 (+ 1 c.c.)
1 sample (about 3 per cent.) negative 1 c.c.

These results may be shown in the following diagram (each dot represents one per cent.) as follows :—

B. Enteritidis Sporogenes Test.

100 ●●●●●●●●●●●●●●●●●●●● about 20 per cent.

10 ●● about 40 per cent.

1 ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●● about 37 per cent.

About 3 per cent. negative 1 c.c. (none in 1 c.c.)

Bile-salt Glucose Peptone Test.

19 Samples.

6 samples (about 31 per cent.)	100,000 (+	·00001 c.c.)
2 samples (about 10 per cent.)	1,000 (+	·001 c.c.)
6 samples (about 31 per cent.)	100 (+	·01 c.c.)
1 sample (about 5 per cent.)	10 (+	·1 c.c.)
2 samples (about 10 per cent.)	1 (+	1 c.c.)
2 samples (about 10 per cent.)	negative result, $\frac{1}{100}$ c.c.	

These results may be shown in the following diagram (each dot represents one per cent.) as follows:—

Bile-salt Glucose Peptone Test.

100,000	●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●	about 31 per cent.
10,000		
1,000	●●●●●●●●●●	about 10 per cent.
100	●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●	about 31 per cent.
10	●●●●●	about 5 per cent.
1	●●●●●●●●●●	about 10 per cent.

About 10 per cent. negative result $\frac{1}{100}$ c.c.

Frizinghall Effluent from Filter No. 2c.

Total Number of Bacteria (Gelatine at 20° C.) per c.c.

12 Samples.

Average number - - - - - - -	1,766,833
Highest number - - - - - - -	7,900,000
Lowest number - - - - - - -	81,000

Total Number of Bacteria (Agar at 37° C.) per c.c.

27 Samples.

Average number - - - - - - -	138,111
Highest number - - - - - - -	1,106,000
Lowest number - - - - - - -	60

B. Coli Test.

9 Samples.

1 sample 1,000 B. coli (or coli-like microbes) per c.c.
5 samples 100 „ „ „
2 samples, negative result $\frac{1}{100}$ c.c.
1 sample, 1 B. coli per c.c.

Six out of the seven coli-like microbes isolated from these samples were, on the basis of the tests employed, typical B. coli.

Indol Test.

10 samples.

1 sample, negative result $\frac{1}{1000}$ c.c
2 samples, negative result $\frac{1}{100}$ c.c.
3 samples 1,000 (+ ·001 c.c.).
3 samples 100 (+ ·01 c.c.).
1 sample 1 (+ 1 c.c.).

Frizinghall Effluent from Filter No. 2 C.

B. Enteritidis Sporogenes Test.

34 Samples.

3 samples	(about 9 per cent.)	100	(+ ·01 c.c.)
7 „	(about 20 per cent.)	10	(+ ·1 c.c.)
18 „	(about 53 per cent.)	1	(+ 1 c.c.)
6 „	(about 17 per cent.)	negative	1 c.c.

These results may be shown in the following diagram (each dot represents one per cent.) as follows:—

B. Enteritidis Sporogenes Test.

100 ●●●●●●●●● about 9 per cent.

10 ●●●●●●●●●●●●●●●●●●●● about 20 per cent.

about 53 per cent. ●●●●●●

1 ●●●

About 17 per cent. negative 1 c.c. (none in 1 c.c.)

Frizinghall Effluent from Filter No. 2 C.

Bile-salt Glucose Peptone Test.

18 Samples.

1 sample	(about 5 per cent.)	100,000	(+ ·00001 c.c.)
3 samples	(about 17 per cent.)	10,000	(+ ·0001 c.c.)
6 samples	(about 33 per cent.)	1,000	(+ ·001 c.c.)
1 sample	(about 5 per cent.)	100	(+ ·01 c.c.)
1 sample	(about 5 per cent.)	10	(+ ·1 c.c.)
1 sample	(about 5 per cent.)	1	(+ 1 c.c.)
5 samples	(about 28 per cent.)	negative	$\frac{1}{100}$ c.c.

These results may be shown in the following diagram (each dot represents one per cent. of the samples) as follows:—

Bile-salt Glucose Peptone Test.

100,000 ●●●●● about 5 per cent.

10,000 ●●●●●●●●●●●●●●●●● about 17 per cent.

1,000 ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●● about 33 per cent.

100 ●●●●● about 5 per cent.

10 ●●●●● about 5 per cent.

1 ●●●●● about 5 per cent.

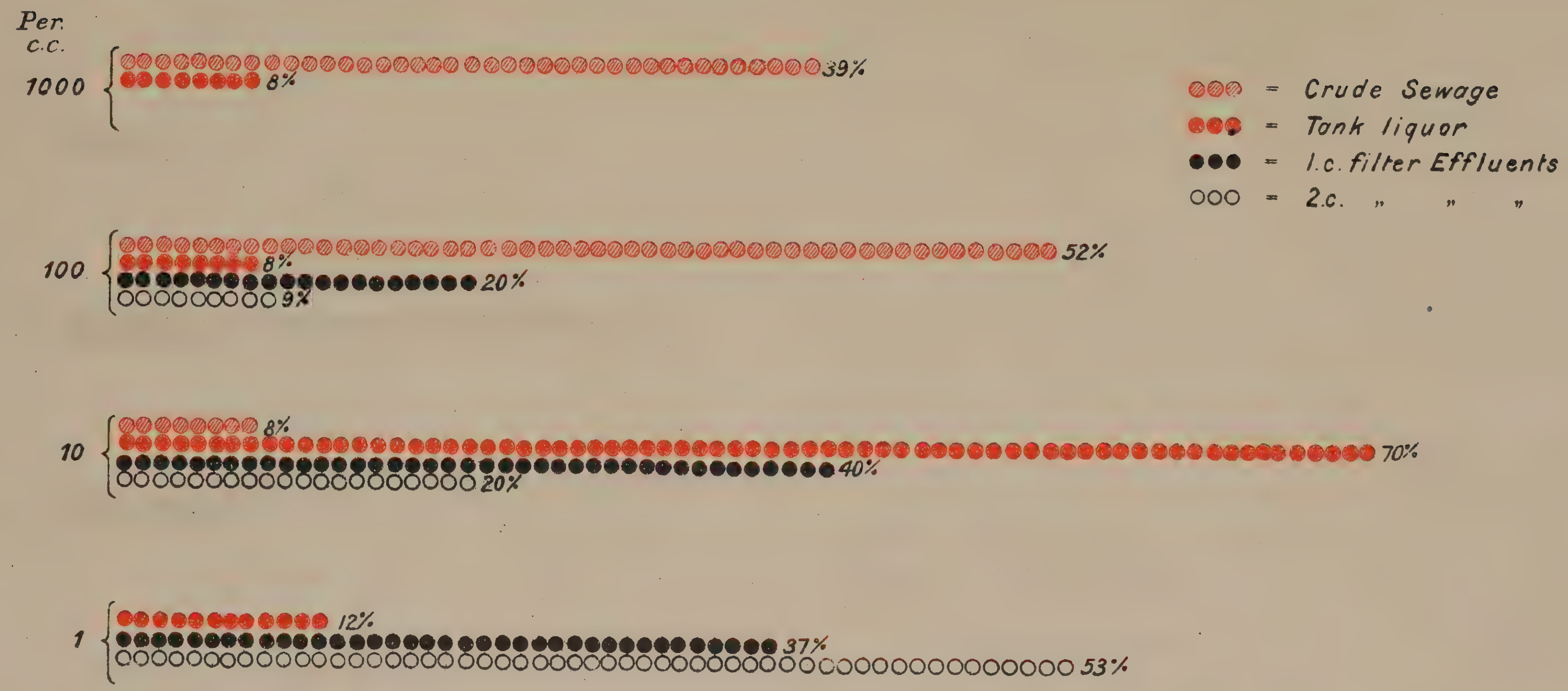
About 28 per cent. negative $\frac{1}{100}$ c.c.

Frizinghall Effluent from Filter No. 3.	Only a few samples were examined. (For records *see* General Table of Results.)
North Bierley samples.	
Samples from Idle Works.	

With the object of showing the marked differences between the crude sewage, tank liquor, and effluents from filters 1 C and 2 C as regards the B. enteritidis sporogenes and bile-salt glucose peptone tests, the two following diagrams (Diagrams B. 1 and B. 2) are given:—

B. I.

B. Enteritidis sporogenes test.



Three and seventeen per cent of the Effluents from Filters I.c. and 2.c. respectively yielded negative results with I c.c.

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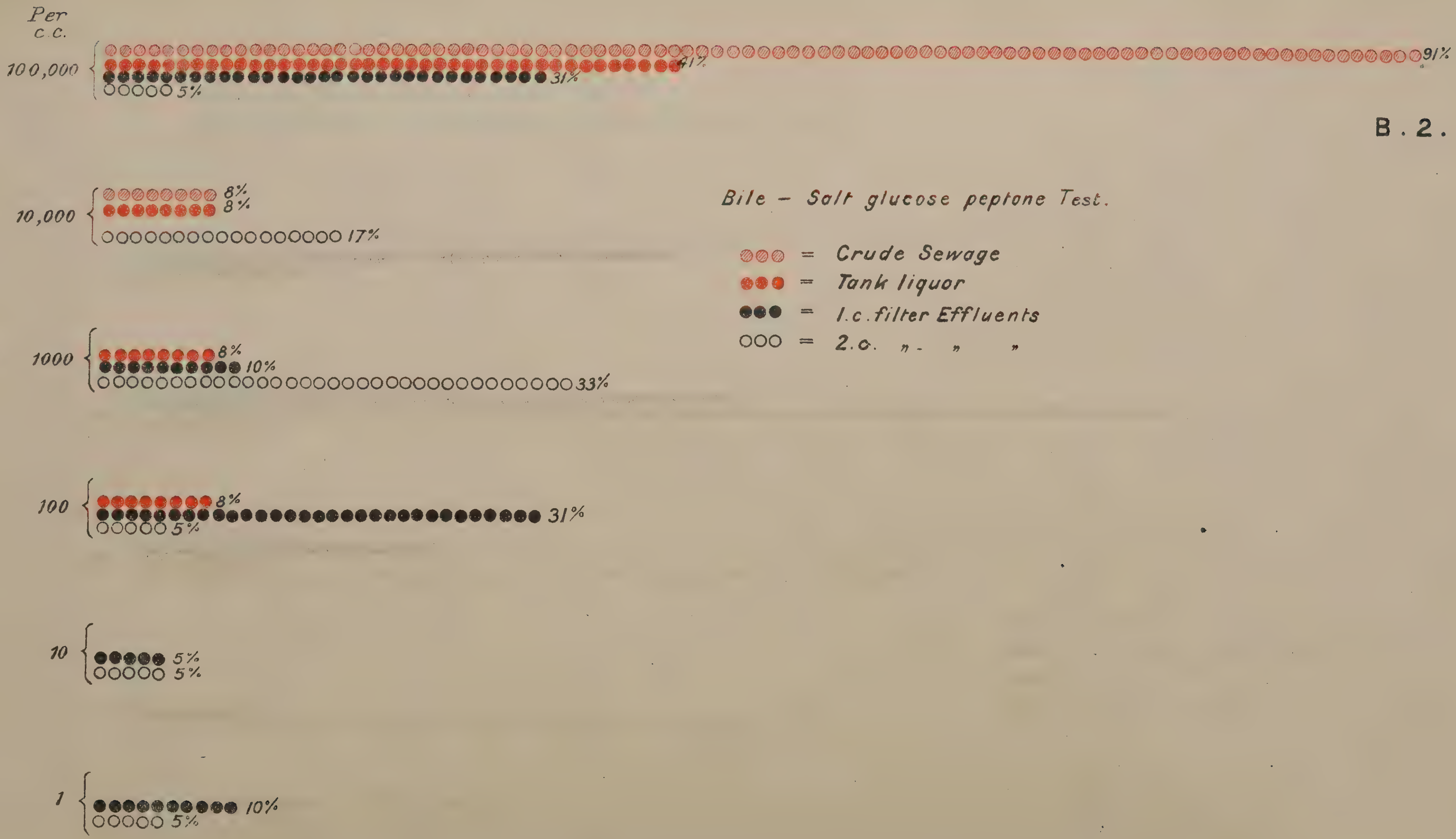
Weller & Graham, Ltd Litho. London.

B . 2 .



33, 10 and 28 per cent of the samples of Tank Liquor, Effluent from 1 c. Filter and Effluent from 2 c. Filter respectively yielded negative results with $1/100$ c.c.

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CONCLUSIONS.

It is apparent that the sulphuric acid treatment, despite its probable advantages in the particular case of Bradford, cannot be relied on to destroy all objectionable bacteria in sewage. Nevertheless, the tank liquor was usually found much purer (bacteriologically) than the crude sewage, and many of the final effluents showed a remarkable degree of percentage purification (*see* diagrams in the text, but more particularly diagrams B. 1 and B. 2).

Bradford sewage contains much trade refuse, and of a kind liable to contain the spores of B. anthracis. On *a priori* grounds the sulphuric acid treatment would seem in the case of Bradford sewage to be specially suitable; for, apart from the recovery of a proportion of the grease, which helps to cover the cost of the sulphuric acid, it is at present impracticable to treat adequately the whole of the sewage. Under existing conditions (1903) a first process, or tank settlement, is all that can be attempted. In effect, a comparatively clear liquid is after only about three hours' settlement, after the addition of the sulphuric acid, discharged into the Bradford Beck. But it must not be supposed that the sulphuric acid treatment is completely successful in killing all objectionable bacteria, even those of non-sporing sort. The results clearly show that the amount of acid present does not suffice to kill all the B. coli and allied non-sporing microbes. It was not therefore anticipated that the highly resistant spores of the B. anthracis would be destroyed. Hence, it is hardly, perhaps, a matter for surprise that the attempt to isolate B. anthracis from the "washings" of one of the filters proved successful. (Addendum A.) At the same time, it is quite conceivable that the sulphuric acid treatment, although it does not kill the spores of bacteria, nor even all the B. coli in the sewage, might nevertheless weaken, or even destroy, the vitality, or might modify the virulence, of some of the less resistant microbes capable of causing specific disease. This, no doubt, is little better than surmise; but it is not impossible that, with a sewage naturally rich in fats, acid treatment in some such form as is adopted at Bradford might, although sterilisation commences instead of ends the treatment, be not altogether undesirable on epidemiological grounds. Moreover, a comparison between the results of the examination of the crude sewage and the tank liquor, as regards spores of B. enteritidis sporogenes, greatly favours the supposition that a large proportion of the spores of B. anthracis, if originally present in the sewage, would be likely to be retained in the sludge. This leads to a consideration of the best means of disposing of the "screenings" of a sewage like the Bradford sewage, which is liable to contain the spores of B. anthracis, and of the sludge produced either by the sulphuric acid or other form of tank treatment.

It is difficult to believe that the manuring of land with matters of this sort may not be a source of danger to grazing cattle. Yet, apart from destruction by fire, which is perhaps impracticable, no reasonable method of killing the highly resistant spores of B. anthracis can be suggested. As, no doubt, the number of spores of B. anthracis would be extremely small in relation to the bulk of solid matter, it might be contended that any danger attaching to the spread of such material over land was outweighed by the practical advantages of this method of disposal. Whether or not such a contention is justifiable is a moot point. But, at all events, it seems desirable to point out that the grazing of cattle on land which has previously been manured with refuse of this description should, if possible, be avoided.

ADDENDUM A.

Recovery of B. Anthracis from the "Washings" of One of the Coal Filters at Bradford.

On September 30th, 1902, I obtained samples of the material (coal) from one of the bacterial filters at Bradford.

The samples of coal were taken from (a) the top layers, (b) 2 feet, (c) 3 feet, and (d) 4 feet below the surface.

Approximately equal quantities of each sample (a, b, c, d) were mixed together. 283 grammes of the mixture were placed in a wide-mouthed sterile bottle containing 200 c.c. of sterile water. After prolonged shaking 50 c.c. of the "washings" of the coal were poured into a sterile 100 c.c. measuring cylinder, and diluted with 50 c.c. of sterile water (called dilution I.). 50 c.c of dilution I. were further diluted with 50 c.c. of sterile water (called dilution II.). 50 c.c. of dilution II. were again diluted with 50 c.c. of sterile water (called dilution III.)

2 c.c. of dilution III. were injected subcutaneously into a guinea-pig.

The rodent was found dead on the fifth day, and the organs and tissues of the body were swarming with B. anthracis. Agar cultures, made from the heart's blood and spleen, yielded the anthrax bacillus in pure culture. The accompanying micro-photograph is of a microscopic smear preparation of the splenic juice of the dead rodent. The preparation was stained by Gram's method. The magnification is 500 diameters.

It is of interest to recall the fact that at Yeovil anthrax was found to be present in—(1) septic tank liquor; (2) septic tank sludge; (3) primary coarse coke bed; (4) secondary fine coke bed; (5) final catchpit of a hide factory; (6) mud of River Yeo; and (7) mud of Yeo Brook.* The Bradford coal filter is thus the eighth source from which B. anthracis has been recovered.

Some experiments were also made with the sludge produced by the sulphuric acid treatment at Bradford. The sample was obtained on August 26th, 1902. Ninety grammes of the sludge were shaken with 100 c.c. of water in a sterile wide-mouthed stoppered bottle. 20 c.c. of this mixture were poured into a sterile tube (called I.); 100 c.c. of sterile water were added to the bottle, and after shaking 20 c.c. were poured into a second tube (called II.); another 100 c.c. of sterile water were added to the bottle, and after shaking 20 c.c. were poured into a third tube (called III.). Next 10 c.c. of the mixture in the bottle were diluted to 100 c.c. with sterile water, and after shaking 20 c.c. were poured into a fourth tube (called IV.).

The four tubes (I., II., III., and IV.) were next heated to 80° C. for ten minutes. Four guinea-pigs were severally inoculated subcutaneously with material from these four tubes.

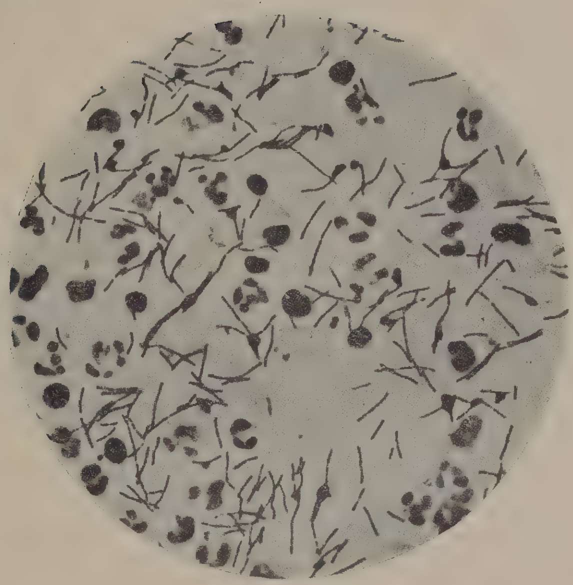
(A.)	rodent	received	$\frac{1}{3}$ c.c.	of tube	I.
(B.)	"	"	$\frac{1}{2}$ c.c.	"	II.
(C.)	"	"	2 c.c.	"	III.
(D.)	"	"	2 c.c.	"	IV.

Two mice were also inoculated by rubbing a little of the sludge into a pouch under the skin. The pouch was produced by making a slight incision on the back with a knife, and then with a suitable instrument loosening the skin from the subjacent tissue.

By the second day all the animals were dead, and, although B. anthracis could not be isolated from the organs or tissues, this result may possibly have been due to the animals succumbing so rapidly from the development of other pathogenic bacteria that the B. anthracis had not sufficient time to multiply. However this may be, the negative result in no way proves that anthrax was not present in the sludge. Indeed, the results obtained with the coal filter "washings" make it almost certain that the sludge must occasionally, if not invariably, contain the spores of B. anthracis. The practical difficulty experienced in experiments of this kind is the impossibility of using other than fractional amounts of material for inoculation purposes, in order to avoid killing the animals before the anthrax bacillus has had time to multiply in the body.

The experiments, although negative as regards anthrax, show the virulent qualities of sludge in the case of rodents and mice.

* Second Report of Royal Commission on Sewage Disposal.



Microscopic smear preparation of the splenic juice of a rodent dead of anthrax after inoculation with the "washings" from one of the coal filters at Bradford. Stained by Gram's method. [Magnification, 500.]

[To face page 296.

ADDENDUM B.

Additional Notes.

Mr. Joseph Garfield, Assoc.M.Inst.C.E., Engineer of the Bradford Sewage Works, has been kind enough to supply me with the following notes*:—

Frizinghall Works.

The sewage (12,000,000 gallons) after screening was treated with sulphuric acid. The amount of acid varied from time to time, the object being to "curdle" or "crack" the sewage. In effect the sewage was not only neutralised but rendered slightly acid. On the average the proportion of acid used was six grains per gallon in excess of that required to neutralise.

The acid sewage was passed through a series of settling tanks (about three hours' settlement). Part of the comparatively clear tank liquor was further treated on the experimental filters, the rest was discharged into the Bradford Beck.

As regards the acid sludge, this was filter-pressed for the extraction of grease.

North Bierley Works.

As regards the North Bierley Works, the following brief notes are of interest:—The sewage (1,000,000 gallons) was treated with alumino-ferric and lime, and passed into settling tanks. The tank liquid was further treated on five acres of filters, composed of five feet of coal shales, with nine inches of soil on the surface. The tank effluent water was distributed over the surface by means of grips cut in the soil.

Idle Works.

In connection with the results of the bacteriological examination of the samples, the following brief notes may be of interest:—The sewage (150,000 gallons) was treated with alumino-ferric and discharged, without settlement, on to areas of land which had been made level and banked round. The land filter effluents discharged direct to the River Aire.

In respect of the filters, the following notes are of interest.

Filter 1c.—Depth, 5 feet; area, 28 square yards. Whole depth, composed of washed coal smudge, varying from $\frac{3}{4}$ inch at bottom to $\frac{1}{8}$ inch at top. Distribution of liquor on surface by means of pipes, having an outlet for each square yard of filter surface. Volume filtered, 50 gallons per square yard in 24 hours, in 24 equal volumes, discharged at intervals varying from 20 minutes at midday to two hours at night.

Filter 2c.—Five feet deep, all fine washed coal smudge, circular in plan, area 13 square yards, and liquor distributed by means of a revolving spreader, worked 12 times in 24 hours, at intervals varying from one hour at midday to four hours at night.

Volume treated on filter, 50 gallons per square yard.

Filter 3.—This filter was composed of boiler clinkers. Depth, 5 feet; area, 30 square yards. The tank liquor was distributed by means of pipes having one outlet for each square yard of surface. Volume treated, 50 gallons per square yard in 24 hours in 24 equal volumes, discharged at intervals varying from 20 minutes at midday to two hours at night.

* I am also greatly indebted to Mr. Garfield for sending me samples from time to time during 1902 and 1903, and for many valuable suggestions in connection with the work.

ILFORD.

Results of the Bacteriological Examination of Samples, as under :—

CRUDE SEWAGE.

TANK LIQUOR.

EFFLUENTS FROM SHALLOW FILTER.

EFFLUENTS FROM DEEP FILTER.

A. C. HOUSTON,

July 24th 1904.

Results of the Bacteriological Examination

1						2		3						4			
Description of the Sample.						Total Number of Bacteria in 1 c.c.		Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method).						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection.				Other Details.									Gas.	Indol.	(a) Acidity. (b) Clot. (Litmus milk cultures, 5 days at 37° C.)	
	Hour.	Day.	Month.	Year.		Gelatine at 20 C°.	Agar at 37 C°.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	(Gelatine "shake" cultures, 24 hrs. at 20° C.)	(Broth cultures, 5 days at 37° C.)	(a)	(b)
44 ..	—	9	8	1901	Ilford crude sewage		5,960,000						+	+	+	+	+
— ..	—	15	8	1901	Ilford crude sewage		8,900,000						+	+	+	+	+
65 ..	—	23	8	1901	Ilford crude sewage		4,900,000						+	+	+	+	+
72 ..	—	27	8	1901	Ilford crude sewage		3,660,000						+	+	+	+	+
82 ..	4 p.m.	18	9	1901	Ilford crude sewage	63,200,000	7,200,000						+	+	+	+	+
A ..	—	28	10	1901	Ilford crude sewage	36,200,000	8,240,000										
E ..	—	29	10	1901	Ilford crude sewage												
581 ..	24 hours average	14	7	1903	Ilford crude sewage												
583 ..	24 hours average	15	7	1903	Ilford crude sewage												
585 ..	24 hours average	16	7	1903	Ilford crude sewage												
587 ..	24 hours average	16	7	1903	Ilford crude sewage (taken over weir lip)												
AVERAGES						49,700,000	6,476,667	5 samples at 100,000 per c.c.						5 out of 5, both indol and clot			

OF ILFORD CRUDE SEWAGE.

5						6						7						8						9
Indol Test. Indol in broth cultures direct (5 days at 37° C).						B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						"Gas" Test. "Gas" production in gelatine "shake" cultures, 24 hours at 20° C.						Neutral-red Broth Test. Greenish-yellow fluorescence, 48 hours at 37° C.						REMARKS.
1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	
1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	
					+																			
					+																			
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									+	–													+	
								+	–														+	
								+	–														+	
									+	–													+	
6 samples at 100,000 per c.c.						3 samples at 100, 4 " " 1,000, 2 " " 10,000 per c.c.						Varied from + ·01 to + ·0001 c.c. (24 hours at 20° C.)						9 samples at 100,000 per c.c.						

Results of the Bacteriological Examination

No.	Time of Collection. Hour.	Day.	Month.	Year.	Other Details.	Total Number of Bacteria in 1 c.c. Gelatine at 20° C.	Agar at 37° C.	Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method). 1 — 1 c.c.	10 — ·1 c.c.	100 — ·01 c.c.	1,000 — ·001 c.c.	10,000 — ·0001 c.c.	100,000 — ·00001 c.c.	Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3. Gas. (Gelatine "shake" cultures, 24 hrs. at 20° C.)	Indol. (Broth cultures, 5 days at 37° C.)	(a) Acidity. (b) Clot. (Litmus milk cultures, 5 days at 37° C.) (a)	(b)
	1					2		3						4			
41 ..	—	6	8	1901	Ilford tank liquor		1,040,000						+	+	+	+	+
48 ..	2.15 p.m.	12	8	1901	Ilford tank liquor		590,000						+	+	+	+	+
60 ..	—	19	8	1901	Ilford tank liquor		1,200,000						+	+	—	+	+
66 ..	10.45 a.m.	22	8	1901	Ilford tank liquor												
73 ..	10.30 a.m.	28	8	1901	Ilford tank liquor	560,000	260,000					+					
76 ..	—	2	9	1901	Ilford tank liquor	4,600,000	1,200,000						+	+	—	+	+
83 ..	—	18	9	1901	Ilford tank liquor	8,400,000	980,000						+	+	+	+	+
B	—	28	10	1901	Ilford tank liquor	8,400,000	1,930,000						+				
F	—	29	10	1901	Ilford tank liquor												
I	—	11	11	1901	Ilford tank liquor												
532 ..	24 hours average	14	7	1901	Ilford tank liquor												
584 ..	24 hours average	15	7	1901	Ilford tank liquor												
586 ..	24 hours average	16	7	1901	Ilford tank liquor												
					AVERAGES ..	5,490,000	1,028,543	1 sample at 10,000 per c.c.; 6 " " 100,000 per c.c.						3 out of 5, both indol and clot; 2 out of 5 clot, but no indol			

ILFORD SEPTIC TANK LIQUOR.

5					6						7						8						9
Indol Test. ndol in broth cultures direct (5 days at 37° C).					B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						"Gas" Test. "Gas" production in gelatine "shake" cultures, 24 hours at 20° C.						Neutral-red Broth Test. Greenish-yellow fluorescence, 48 hours at 37° C.						REMARKS.
10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	
				+																			
				+																			
				+		+	−					+	−				At least 1,000						
							+	−				+	−				At least 1,000						
			+				+	−				+	−								+	−	
				+				+	−			+	−									+	
				+				+	−					+	−							+	
				+					+	−			+	−								+	
								+	−				+	−								+	
							+	−					+	−								+	
						+	−															+	
							+	−														+	
							+	−														+	
1 sample at 10,000 per c.c.; 6 " " 100,000 per c.c.					2 sample at 10; 5 " " 100; 3 " " 1,000; 1 " " 10,000 per c.c.						Usually from + ·1 to + ·01 c.c. (24 hours at 20° C.)						2 samples at least 1,000; 1 " " 10,000; 8 " " 100,000 per c.c.						

RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF

1						2		3						4			
Description of the Sample.						Total Number of Bacteria in 1 c.c.		Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method).						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection.				Other Details.									Gas.	Indol.	(a) Acidity. (b) Clot. (Litmusmilk cultures. 5 days at 37° C.)	
	Hour.	Day.	Month.	Year.		Gelatine at 20 C°.	Agar at 37 C°.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	(Gelatine "shake" cultures, 24 hrs. at 20° C.)	(Broth cultures, 5 days at 37° C.)	(a)	(b)
43 ..	—	6	8	1901	Effluent from shallow filter		980,000						+	+	+	+	+
50 ..	—	12	8	1901	Effluent from shallow filter		520,000						+	+	+	+	+
62 ..	—	19	8	1901	Effluent from shallow filter		500,000						+	+	—	+	+
68 ..	10.55 a.m.	22	8	1901	Effluent from shallow filter												
75 ..	—	27	8	1901	Effluent from shallow filter		964,000						+	+	+	+	+
78 ..	—	2	9	1901	Effluent from shallow filter	13,200,000	900,000						+	+	+	+	+
85 ..	—	18	9	1901	Effluent from shallow filter	9,900,000	760,000						+	+	+	+	+
D	—	28	10	1901	Effluent from shallow filter	18,800,000	1,340,000					+					
H	—	29	10	1901	Effluent from shallow filter												
J	—	11	11	1901	Effluent from shallow filter	2,500,000	440,000					+					
AVERAGES :						11,100,000	800,500	2 samples at 10,000 per c.c.; 6 „ „ 100,000 per c.c.						5 out of 6, both indol and clot; 1 out of 6, clot but no indol			

THE EFFLUENTS OF THE SHALLOW FILTER AT ILFORD.

5						6						7						8						9
Indol Test. Indol in broth cultures direct (5 days at 37° C).						B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						"Gas" Test. "Gas" production in gelatine "shake" cultures, 24 hours at 20° C.						Neutral-red Broth Test. Greenish-yellow fluorescence, 48 hours at 37° C.						REMARKS.
1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	
1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	
					+																			
					+																			
					+		+	–					+	–				At least 1,000						
							+	–					+	–				At least 1,000						
					+			+	–					+	–								+	
					+				+	–			+	–									+	
					+			+	–					+	–								+	
				+	–					+	–			+	–								+	
									+	–				+	–								+	
					+				+	–				+	–								+	
1 sample at 10,000 } per 7 " " 100,000 } c.c.						2 samples at 10 } 2 " " 100 } per 3 " " 1,000 } c.c. 1 " " 10,000 }						Varied from + ·1 to + ·01 c.c. (24 hours at 20° C.)						2 samples at least 1,000 } per 6 " " 100,000 } c.c.						

RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF

1. Description of the Sample. No.	Time of Collection. Hour.	Day.	Month.	Year.	Other Details.	2. Total Number of Bacteria in 1 c.c. Gelatine at 20 C°.	Agar at 37 C°.	3. Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method). 1 — 1 c.c.	10 — ·1 c.c.	100 — ·01 c.c	1,000 — ·001 c.c.	10,000 — ·0001 c.c.	100,000 — ·00001 c.c.	4. Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3. Gas. ("Gelatine" shake cultures, 24 hrs. at 20° C.)	Indol. (Broth cultures, 5 days at 37° C.)	(a) Acidity. (b) Clot. (Litmusmilk cultures, 5 days at 37° C.) (a)	(b)
42 ..	—	6	8	1901	Effluent from deep filter		938,000						+	+	+	+	+
49 ..	—	12	8	1901	Effluent from deep filter		460,000						+	+	—	alk.	—
61 ..	—	19	8	1901	Effluent from deep filter		700,000						+	+	+	+	+
67 ..	10.53 a.m.	22	8	1901	Effluent from deep filter												
74 ..	—	27	8	1901	Effluent from deep filter		264 000						+	+	+	+	+
77 ..	—	2	9	1901	Effluent from deep filter	9,400,000	660,000						+	+	+	+	+
84 ..	—	18	9	1901	Effluent from deep filter	20,000,000	650,000						+	+	+	+	+
C	—	28	10	1901	Effluent from deep filter	17,700,000	850,000					+					
G	—	29	10	1901	Effluent from deep filter												
K	—	11	11	1901	Effluent from deep filter	1,900,000	430,000						+				
					AVERAGES ..	12,250,000	619,000	1 sample at 10,000 per c.c.; 7 „ „ 100,000 per c.c.						5 out of 6, both indol and clot; 1 out of 6, neither indol nor clot			

THE EFFLUENT FROM THE DEEP FILTER AT ILFORD.

5						6						7						8						9
Indol Test. Indol in broth cultures direct (5 days at 37° C).						B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						"Gas" Test. "Gas" production in gelatine "shake" cultures, 24 hours at 20° C.						Neutral-red Broth Test. Greenish-yellow fluorescence, 48 hours at 37° C.						REMARKS.
1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	
1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	
					+																			
					+																			
					+		+	–					+	–					At l	east	1,000			
							+	–					+	–					At l	east	1,000			
					+			+	–					+	–								+	
					+			+	–				+	–									+	
					+				+	–				+	–								+	
				+	–			+						–									+	
										+	–			+	–								+	
					+			+	–					+	–							+		
1 sample at 10,000 } per c.c. 7 " " 100,000 }						2 samples at 10; 4 " " 100; 1 " " 1,000; 1 " " 10,000 } per c.c.						Varied from + ·1 to + ·01 c.c. (24 hours at 20°)						2 samples at least 1,000; 1 " " 10,000; 100,000 } per c.c						

LEEDS.

Results of the Bacteriological Examination of:—

CRUDE AND SCREENED SEWAGES.
SEPTIC TANK LIQUORS.
NEW LEEDS FILTER EFFLUENTS.
NEW LEEDS FILTER EFFLUENTS AFTER SETTLEMENT.
NEW LEEDS FILTER EFFLUENTS AFTER SETTLEMENT AND FILTRATION.
OLD LEEDS FILTER EFFLUENTS.
MANCHESTER BED EFFLUENTS.
DUCAT FILTER EFFLUENTS.
CAMERON BED EFFLUENTS.
WHITTAKER BED EFFLUENTS.
WHITTAKER BED EFFLUENTS AFTER FILTRATION.

CONTENTS.

A. C. HOUSTON.

July 20, 1904.

Results of the Bacteriological Examination of Leeds Crude Sewage

1						2						3						4			
Description of the Sample.						B.S. = Bile Salt Glucose Peptone Test (+ = acid and gas). L.P.M. = Lactose Peptone Milk Test (+ = acid gas and clot).						Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method).						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection. Hour.	Day.	Month.	Year.	Other Details.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	Gas. (Gelatine "shake" cultures, 24 hrs. at 20° C.)	Indol. (Broth cultures, 5 days at 37° C.)	(a) Acidity. (b) Clot. (Litmus milk cultures, 5 days at 37° C.) (a)	(b)
1 ..	10 a.m.–6 p.m.	4	2	1902	Crude Sewage, average sample ..						B.S. +										
2 ..	10 a.m.–4 p.m.	12	2	1902	Crude Sewage						B.S. +										
3 ..	9 a.m.–4.30 p.m.	19	2	1902	Crude Sewage					B.S. +	—										
4 ..	9 a.m.–4 p.m.	25	2	1902	Crude Sewage						B.S. +										
5 ..	9 a.m.–4 p.m.	4	3	1902	Crude Sewage						B.S. +										
6 ..	9 a.m.–4 p.m.	12	3	1902	Crude Sewage					L.P.M. +	B.S. +										
7 ..	10 a.m.–4 p.m.	19	3	1902	Crude Sewage						B.S. + L.P.M.										
8 ..	2.15 p.m.	2	4	1902	Crude Sewage, chance sample ..						B.S. + L.P.M.										
9 ..	—	7-8	4	1902	Crude Sewage												+	+	—	+	+
10 ..	24 hours	14	4	1902	Crude Sewage											+	—	+	+	+	+
11 ..	—	26	4	1902	Crude Sewage, chance sample ..					L.P.M. +	—										
12 ..	24 hours	15-16	5	1902	Crude Sewage												+	+	+	+	+
13 ..	24 hours	28	5	1902	Crude Sewage																
14 ..	24 hours	11-12	6	1902	Crude Sewage												+	+	+	+	+
15 ..	—	18-19	6	1902	Crude Sewage											+	—	+	+	+	+
16 ..	—	5	7	1902	Crude Sewage																
17 ..	24 hours	12	8	1902	Crude Sewage																
18 ..	—	15	8	1902	Crude Sewage, chance sample ..												+	+	+	+	+
19 ..	—	30	8	1902	Crude Sewage, chance sample ..						B.S. + L.P.M.						+	+	+	+	+
20 ..	—	7	10	1902	Crude Sewage						B.S + L.P.M.						+	+	+	+	+
21 ..	—	20	10	1902	Crude Sewage, chance sample ..						B.S. + L.P.M.						+	+	+	+	—
22 ..	24 hours	23	10	1902	Crude Sewage						B.S. + L.P.M.						+	+	—	+	—
23 ..	24 hours	30	10	1902	Crude Sewage																
24 ..	24 hours	12	11	1902	Crude Sewage																

ND LEEDS SCREENED SEWAGE FOR NEW AND OLD LEEDS FILTERS.

5						6						7						8						9
Indol Test. Indol in broth cultures direct (5 days at 37° C).						B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						"Gas" Test. "Gas production in gelatine "shake" cultures, 24 hours at 20° C.						Neutral-red Broth Test Greenish-yellow fluorescence, 48 hours at 37° C.						REMARKS.
1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	
1 c.c.	.1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	
								+	−						+	−						+	−	
									+	−				+	−								+	
								+	−					+	−								+	
									+	−					+	−							+	
									+	−				+	−								+	
										+						+							+	
									+	−				+	−								+	
								+	−						+	−							+	
					+																			Gelatine at 20°C. .5000,000; Agar at 37° C., 700,000 } microbes per c.c.
				+	−																			Gelatine at 20° C. 49,000,000; Agar at 37° C. 5,100,000 } microbes per c.c.
					+			+	−													+	−	
									+	−														
				+	−			+	−															
				+	−				+	−														
									+	−														
																								No streptococci could be found in ·001 c.c. agar (at 37° C.)
					+				+	−					24 hrs. +	−	48 hrs. +						+	
					+				+	−													+	
					+			+	−														+	
					+				+	−													+	
					+				+	−													+	
								+	−															Agar at 37° C. 1,900,000 microbes per c.c.
									+	−														Agar at 37° C. 1,700,000 microbes per c.c. Cane-sugar test + ·0001; —·00001 c.c.

RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF LEEDS CRUDE SEWAGE

1						2						3						4			
Description of the Sample.						B.S. = Bile Salt Glucose Peptone Test (+ = acid and gas). L.P.M. = Lactose Peptone Milk Test (+ = acid gas and clot).						Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method).						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection.				Other Details.	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	Gas. (Gelatine "shake" cultures, 24 hrs. at 20° C.)	Indol (Broth cultures, 5 days at 37° C.)	(a) Acidity. (b) Clot. (Litmus milk cultures, 5 days at 37° C.)	
	Hour.	Day.	Month.	Year.		1 c.c.	·1 c.c.	·01 c.c.	001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.			(a)	(b)
25 ..	4.25 p.m.	28	1	1902	Screened Sewage going into New Leeds Bed, chance sample						B.S. +										
26 ..	10 p.m.–6 a.m.	5	2	1902	Screened Sewage for New Leeds Filter											+	—	+	+	Alkali	—
27 ..	24 hours	20	2	1902	Screened Sewage sent on to New Leeds Filter												+	+	—	+	—
28 ..	24 hours	25	2	1902	Screened Sewage going on to New Leeds Bed												+	+	+	+	+
29 ..	9 a.m.–4 p.m.	4	3	1902	Screened Sewage for New Leeds Filter						B.S. +										
30 ..	9 a.m.–4 p.m.	12	3	1902	Screened Sewage for New Leeds Filter					L.P.M. +	B.S. +										
31 ..	12 a.m.–4 p.m.	19	3	1902	Screened Sewage for New Leeds Filter						B.S. + L.P.M.										
32 ..	24 hours	14	4	1902	Screened Sewage for New Leeds Filter						B.S. + L.P.M.										
33 ..	24 hours	20	2	1902	Screened Sewage for Old Leeds Filter											+	—	+	+	+	+
34 ..	—	25	2	1902	Screened Sewage, 24 hours average going on to Old Leeds Bed						B.S. +										
35 ...	24 hours	4	3	1902	Screened Sewage for Old Leeds Filter											+	—	+	+	+	+
36 ..	24 hours	12	3	1902	Screened Sewage for Old Leeds Filter												+	+	—	Alkali	—
37 ..	12 a.m.–4 p.m.	19	3	1902	Screened Sewage for Old Leeds Filter						B.S. + L.P.M.										
38 ..	2.20 p.m.	2	4	1902	Screened Sewage going on to Old Leeds Filter (chance)					B.S. +	L.P.M. +										
39 ..	24 hours	28	4	1902	Screened Sewage for Old Leeds Filter					B.S. +	L.P.M. +										
AVERAGES: Inclusive of all the results.						Bile salt glucose peptone test:— 3 samples at 10,000, 18 " " 100,000 } per c.c. Lactose peptone milk test:— 3 samples at 10,000, 11 " " 100,000 } per c.c.						5 samples at 10,000, 11 " " 100,000 } per c.c.						10 out of 16, both indol and clot. 3 out of 16, neither indol nor clot. 1 out of 16, clot but no indol. 2 out of 16, indol but no clot.			

AND LEEDS SCREENED SEWAGE FOR NEW AND OLD LEEDS FILTERS—*Continued.*

5						6						7						8						9
Indol Test. Indol in broth cultures direct (5 days at 37° C).						B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						"Gas" Test. "Gas production in gelatine "shake" cultures, 24 hours at 20° C.						Neutral-red Broth Test Greenish-yellow fluorescence, 48 hours at 37° C.						REMARKS.
1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	
1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	
								+	–						+	–							+	
				+	–																			Gelatine at 20° C. 16,000,000 Agar at 37° C. 530,000 microbes per c.c.
				+	–																			Gelatine at 20° C. 50,000,000 Agar at 37° C. 3,500,000 microbes per c.c.
					+																			Gelatine at 20° C. 86,000,000 Agar at 37° C. 3,000,000 microbes per c.c.
										+					+	–							+	
									+	–						+							+	
									+	–				+	–								+	
					+				+	–					+	–							+	
				+	–																			Gelatine at 20° C. 31,000,000 Agar at 37° C. 520,000 microbes per c.c.
									+	–				+	–							+	–	
					+																			Gelatine at 20° C. 10 000,000 Agar at 37° C. 100,000 microbes per c.c.
					+																			Gelatine at 20° C. 25,000,000 Agar at 37° C. 660,000 microbes per c.c.
									+	–				+	–								+	
									+	–					+	–							+	
									+	–					+	–							+	
6 samples at 10,000 per c.c.; 11 " " 100,000 per c.c.						8 samples at 100; 19 " " 1,000; 2 " " 10,000 per c.c.						Usually from +·01 to +·001c.c. (24 hours at 20° C.)						3 samples at 10,000 per c.c.; 20 " 100,000 per c.c.						Gelatine at 20° C. 39,625,000 Agar at 37° C. 2,271,000 microbes per c.c.

RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF OPEN SEPTIC TANK LIQUOR FOR WHITTAKER BEDS; CLOSED SEPTIC TAN

1						2						3						4			
Description of the Sample.						B.S. = Bile Salt Glucose Peptone Test (+ = acid and gas). L.P.M. = Lactose Peptone Milk Test (+ = acid gas and clot).						Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method).						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection.				Other Details.													Gas.	Indol.	(a) Acidity. (b) Clot. (Litmus milk cultures, 5 days at 37° C.)	
	Hour.	Day.	Month.	Year.		1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	(Gelatine "shake" cultures, 24 hrs. at 20° C.)	(Broth cultures, 5 days at 37° C.)		
						1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.			(a)	(b)
1 ..	4.30 p.m.	28	1	1902	Open Septic Tank Liquor. Chance sample						B.S. +										
2 ..	10 a.m.– 6 p.m.	4	2	1902	Whittaker Effluent from Open Septic Tank, Nos. 1, 2, and 3						B.S. +										
3 ..	10 a.m.– 4 p.m.	12	2	1902	Septic Tanks 1, 2, and 3 sent on to Whittaker Bed						B.S. +										
4 ..	9 a.m.– 4.30 p.m.	19	2	1902	Septic Tank Liquor for Whittaker Bed						B.S. +										
5 ..	9 a.m.– 4 p.m.	25	2	1902	Septic Tank Liquor for Whittaker Bed						B.S. +										
6 ..	9 a.m.– 4 p.m.	4	3	1902	Septic Tank Liquor for Whittaker Bed				B.S. +	—											
7 ..	9 a.m.– 4 p.m.	12	3	1902	Septic Tank Liquor for Whittaker Bed						B.S. +										
8 ..	10 a.m.– 4 p.m.	19	3	1902	Septic Tank Liquor for Whittaker Bed				L.P.M +	B.S. +	—										
9 ..	—	2	4	1902	Open Septic Tank Liquor going on to Whittaker Bed (chance)						B.S. + L.P.M.										
10 ..	24 hours	7–8	4	1902	Septic Tank Liquor for Whittaker Bed				L.P.M +	B.S. +	—										
11 ..	24 hours	14	4	1902	Septic Tank Liquor for Whittaker Bed											+	–	+	+	+	+
12 ..	—	26	4	1902	Septic Tank Liquor for Whittaker Bed (chance sample)						L.P.M. +										
13 ..	24 hours	7	5	1902	Septic Tank Liquor for Whittaker Bed					B.S. + L.P.M.	—										
14 ..	24 hours	11–12	6	1902	Septic Tank Liquor											+	—	+	+	+	+
15 ..	—	26	8	1902	Septic Tank Liquor, chance sample												+	+	+	+	+
16 ..	—	4	3	1903	Septic Tank Liquor as sent on to Whittaker Bed																
17 ..	10 a.m.– 6 p.m.	4	2	1902	Closed Septic Tank Liquor for Cameron Bed						B.S. +										
18 ..	10 a.m.– 4 p.m.	12	2	1902	Closed Septic Tank Liquor						B.S. +										
19 ..	9 a.m.– 4.30 p.m.	19	2	1902	Covered Septic Tank Liquor ..						B.S. +										
20 ..	9 a.m.– 4 p.m.	25	2	1902	Covered Septic Tank Liquor ..						B.S. +										
21 ..	9 a.m.– 4 p.m.	4	3	1902	Closed Septic Tank Liquor ..						B.S. +										
22 ..	10 a.m.– 4 p.m.	19	3	1902	Closed Septic Tank Liquor ..											+	–	+	–	+	–
23 ..	2.30 p.m.	2	4	1902	Closed Septic Tank Liquor (chance sample)						B.S. + L.P.M.										
24 ..	24 hours	7–8	4	1902	Septic Tank Liquors for Cameron Beds					B.S. + L.P.M.	—										
25 ..	24 hours	14	4	1902	Closed Septic Tank Liquor ..				L.P.M +	B.S. +	—										
26 ..	24 hours	7	5	1902	Closed Septic Tank Liquor ..											+	—	+	+	+	+

LIQUOR FOR CAMERON BEDS; OPEN SEPTIC TANK LIQUOR FOR DUCAT BED; AND OPEN SEPTIC TANK LIQUOR FOR MANCHESTER BEDS.

5						6						7						8						9
Indol Test. Indol in broth cultures direct (5 days at 37° C).						B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						"Gas" Test. "Gas" production in gelatine "shake" cultures, 24 hours at 20° C.						Neutral-red Broth Test. Greenish-yellow fluorescence, 48 hours at 37° C.						REMARKS.
1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	
1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	
								+	–					+	–							+	–	
							+	–						+	–							+	–	
								+	–				+	–								+	–	
								+	–				+	–								+	–	
								+	–				+	–								+	–	
								+	–				+	–									+	
								+	–					+	–								+	
							+	–					+	–									+	
								+	–					+	–								+	
									+	–				+	–							+	–	
					+																			Gelatine at 20° C. 2,100,000, Agar at 37° C. 160,000 } microbes per c.c.
							+	–					+	–								+	–	
				+	–			+	–															
					+			+	–					24 hrs. +	–	48 hrs. +	–						+	
								+	–															Agar at 37° C. 60,000 microbes per c.c.
							+	–						+	–							+	–	
								+	–					+	–								+	
								+	–				+	–									+	
									+	–			+	–								+	–	
								+	–				+	–								+	–	
					+																			Gelatine at 20° C. 1,800,000, Agar at 37° C. 70,000 } microbes per c.c.
																							+	
								+	–					+	–									
								+	–					+	–							+	–	
				+	–			+	–					+	–							+	–	
				+	–																			Gelatine at 20° C. 8,400,000, Agar at 37° C. 230,000 } microbes per c.c.

Results of the Bacteriological Examination of Open Septic Tank Liquor for Whittaker Beds; Closed Septic Tank

1						2						3						4			
Description of the Sample.						B.S. = Bile Salt Glucose Peptone Test (+ = acid and gas). L.P.M. = Lactose Peptone Milk Test (+ = acid gas and clot).						Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method).						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection.				Other Details.													Gas.	Indol.	(a) Acidity. (b) Clot. (Litmus milk cultures, 5 days at 37° C.)	
	Hour.	Day.	Month.	Year.		1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	(Gelatine "shake" cultures, 24 hrs. at 20° C.)	(Broth cultures, 5 days at 37° C.)	(a)	(b)
27 ..	10 a.m.– 6 p.m.	4	2	1902	Open Septic Tank, Nos. 1, 2, and 3, for Ducat Bed						B.S. +										
28 ..	10 a.m.– 4 p.m.	12	2	1902	Septic Tank Liquor, Nos. 1, 2, and 3, for Ducat Bed						B.S. +										
29 ..	9 a.m.– 4.30 p.m.	19	2	1902	Septic Tank Liquor for Ducat Bed						B.S. +										
30 ..	9 a.m.– 4 p.m.	25	2	1902	Septic Tank Liquor for Ducat Bed						B.S. +										
31 ..	9 a.m.– 4 p.m.	4	3	1902	Septic Tank Liquor for Ducat Bed						B.S. +										
32 ..	9 a.m.– 4 p.m.	12	3	1902	Septic Tank Liquor for Ducat Bed						B.S. +										
33 ..	10 a.m.– 4 p.m.	19	3	1902	Septic Tank Liquor going on to Ducat Bed											+	–	+	–	+	+
34 ..	2.30 p.m.	3	4	1902	Septic Tank Liquor going on to Ducat Bed. Chance sample												+	+	+	+	+
35 ..	24 hours	7–8	4	1902	Septic Tank Liquor for Ducat Bed					B.S. +	L.P.M. +										
36 ..	24 hours	14	4	1902	Septic Tank Liquor for Ducat Bed					L.P.M. +	B.S. +										
37 ..	—	26	4	1902	Septic Tank Liquor for Ducat Bed, chance sample						L.P.M. +										
38 ..	24 hours	7	5	1902	Septic Tank Liquor for Ducat Bed					B.S. + L.P.M.	–										
39 ..	10 a.m.	5	2	1902	Septic Tank Liquor sent on to Manchester Beds, average of 2 fillings										+	–		+	–	+	–
40 ..	—	12	2	1902	Septic Tank Liquor, flowing into No. 1 Bed, average of 2 fillings												+	+	+	+	+
41 ..	—	25	2	1902	Open Septic Tank Liquor, as run on to No. 1 Bed, average of 2 fillings											+	–	+	–	+	–
42 ..	—	4	3	1902	Septic Tank for Manchester Beds. Two fillings											+	–	+	+	+	+
43 ..	—	14	3	1902	Septic Tank Liquor for Manchester Beds. Two fillings											+	–	+	–	+	+
44 ..	24 hours	7	5	1902	Septic Tank Liquor for Manchester Bed										+	–		+	+	+	+

	2	3	4
AVERAGES: Inclusive of all the results.	Bile salt glucose peptone test: 1 sample at 1,000; 7 " " 10,000; 20 " " 100,000 per c.c. Lactose peptone milk test: 3 samples at 1,000; 4 " " 10,000; 5 " " 100,000 per c.c.	2 samples at 1,000; 8 " " 10,000; 3 " " 100,000 per c.c.	8 out of 13, both indol and clot. 3 out of 13, neither indol nor clot. 2 out of 13, clot, but no indol.

LIQUOR FOR CAMERON BEDS; OPEN SEPTIC TANK LIQUOR FOR DUCAT BED; AND OPEN SEPTIC TANK LIQUOR FOR MANCHESTER BEDS.

5						6						7						8						9
Indol Test. Indol in broth cultures direct (5 days at 37° C).						**B. Enteritidis Sporogenes Test.** Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						**"Gas" Test.** "Gas" production in gelatine "shake" cultures, 24 hours at 20° C.						**Neutral-red Broth Test.** Greenish-yellow fluorescence, 48 hours at 37° C.						**REMARKS.**
1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	
1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	
							+	–					+	–							+	–		
							+	–					+	–								+	–	
									+	–				+	–							+	–	
								+	–				+	–									+	
									+	–				+	–								+	
							+	–						+	–							+	–	
			+	–																				Gelatine at 20° C. 340,000 Agar at 37° C. 230,000 microbes per c.c.
					+																			Gelatine at 20° C. 11,000,000 Agar at 37° C. 1,000,000 microbes per c.c.
								+	–					+	–								+	
			+	–				+	–					+	–							+	–	
							+	–					+	–								+	–	
					+																			Gelatine at 20° C. 11,000,000 Agar at 37° C. 820,000 microbes per c.c.
					+																			Gelatine at 20° C. 9,000,000 Agar at 37° C. 670,000 microbes per c.c.
				+	–																			Gelatine at 20° C. 16,000,000 Agar at 37° C. 460,000 microbes per c.c.
				–	–																			Gelatine at 20° C. 7,500,000 Agar at 37° C. 90,000 microbes per c.c.
				+	–																			Gelatine at 20° C. 6,700,000 Agar at 37° C. 680,000 microbes per c.c.
				+	–																			Gelatine at 20° C. 12,000,000 Agar at 37° C. 630,000 microbes per c.c.
2 samples at 1,000 per c.c. 6 „ „ 10,000 per c.c. 6 „ „ 100,000 per c.c. 1 „ negative 1/10,000 c.c.						8 samples at 10 per c.c. 19 „ „ 100 per c.c. 4 „ „ 1,000 per c.c.						Usually from + ·1 to + ·01 c.c. (gelatine at 20° C.)						1 sample at 1,000 per c.c. 17 „ „ 10,000 per c.c. 11 „ „ 100,000 per c.c.						Gelatine at 20° C. 7,803,636 Agar at 37° C. 425,000 microbes per c.c.

RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF

1						2						3						4			
Description of the Sample.						B. S.=Bile Salt Glucose Peptone Test (+ = acid and gas). L.P.M.=Lactose Peptone Milk Test (+ = acid gas and clot).						Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method).						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection.				Other Details.													Gas.	Indol.	(a) Acidity, (b) Clot. (Litmus milk cultures, 5 days at 37° C.)	
	Hour.	Day.	Month.	Year.		1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	(Gelatine "shake" cultures, 24 hrs. at 20° C.)	(Broth cultures, 5 days at 37° C.)	(a)	(b)
1 ..	4.30 p.m.	28	1	1902	Effluent from New Leeds Bed, chance sample					B.S. +	—										
2 ..	10 a.m.	6	2	1902	Effluent from New Leeds Filter										+	—		+	—	+	—
3 ..	24 hours	20	2	1902	Effluent from New Leeds Bed ..											+	—	+	—	—	—
4 ..	24 hours	25	2	1902	Effluent from New Leeds Bed. Average of 24 hours											+	—	+	+	+	+
5 ..	9 a.m.–4 p.m.	4	3	1902	Effluent from New Leeds Bed ..					B.S. +	—										
6 ..	9 a.m.–4 p.m.	12	3	1902	Effluent from New Leeds Filter					B.S. +											
7 ..	12 a.m.–4 p.m.	19	3	1902	Effluent from New Leeds Filter					B.S. + L.P.M.	—										
8 ..	—	24	3	1902	Effluent from New Leeds Filter											+	—	+	+	+	+
9 ..	—	25	3	1902	Effluent from New Leeds Filter			B.S. + L.P.M.	—												
10 ..	2.30 p.m.	2	4	1902	Effluent from New Leeds Filter, chance sample					L.P.M. +	B.S. +										
11 ..	24 hours	14	4	1902	Effluent from New Leeds Filter					B.S. +	L.P.M. +										
12 ..	—	12	5	1902	Effluent from New Leeds Filter, chance sample					B.S. +	L.P.M. +						+	+	+	+	+
13 ..	24 hours	27	5	1902	Effluent from New Leeds Filter, chance sample												+	+	+	+	+
14 ..	24 hours	3	6	1902	Effluent from New Leeds Filter, chance sample																
15 ..	—	10	6	1902	Effluent from New Leeds Filter					B.S. + L.P.M.	—					+	—	+	—	+	—
16 ..	24 hours	11-12	6	1902	Effluent from New Leeds Bed ..										+	—		+	—	+	—
17 ..	—	16	6	1902	Effluent from New Leeds Filter, chance sample											+	—	+	+	+	—
18 ..	—	1	7	1902	Effluent from New Leeds Filter, chance sample											+	—	+	+	—	—
19 ..	—	7	7	1902	Effluent from New Leeds Filter					B.S. + L.P.M.	—										
20 ..	—	16	7	1902	Effluent from New Leeds Filter, chance sample				B.S. +	L.P.M. +	—										
21 ..	—	21	7	1902	Effluent from New Leeds Filter, chance sample																
22 ..	—	5	8	1902	Effluent from New Leeds Filter..				B.S. +	L.P.M. +	—										

THE EFFLUENTS FROM THE NEW LEEDS FILTER.

5. Indol Test. Indol in broth cultures direct (5 days at 37° C).						6. B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						7. "Gas" Test. "Gas production in gelatine "shake" cultures, 24 hours at 20° C.						8. Neutral-red Broth Test. Greenish-yellow fluorescence, 48 hours at 37° C.						9. REMARKS.
1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	
1 c.c.	.1 c.c.	·0 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	
								—						+	—								+	
					+																			Gelatine at 20° C. 2,000,000 / Agar at 37° C. 50,000 microbes per c.c.
			+	—																				Gelatine at 20° C. 2,600,000 / Agar at 37° C. 120,000 microbes per c.c.
				+	—																			Gelatine at 20° C. 1,900,000 / Agar at 37° C. 57,000 microbes per c.c.
								+	—				+	—								+	—	
									+					+	—							+		
								+	—				+	—								+	—	
					+																			Gelatine at 20° C. 5,000,000 / Agar at 37° C. 900,000 microbes per c.c.
								+	—			+	—								+	—		
								+	—					+	—							+		
					+			+	—					+	—							+	—	
				+	—		+V	—						+	—							+	—	V = virulent to guinea-pig.
					+				+														+	
							+	—																
			+	—					+V	—				+	—							+	—	
		+	—					+	—															
			+	—			+	—																No streptococci found in ·001 c.c. Agar at 37° C.
			+	—					+	—				+	—							+	—	
									+	—														
								+	—															
								+	—															
								+	—			+	—								+	—		

RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF

No.	1. Description of the Sample. Time of Collection. Hour.	Day.	Month.	Year.	Other Details.	2. B.S. = Bile Salt Glucose Peptone Test (+ = acid and gas). L.P.M. = Lactose Peptone Milk Test (+ = acid gas and clot). 1 (1 c.c.)	10 (·1 c.c.)	100 (·01 c.c.)	1,000 (·001 c.c.)	10,000 (·0001 c.c.)	100,000 (·00001 c.c.)	3. Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method). 1 (1 c.c.)	10 (·1 c.c.)	100 (·01 c.c.)	1,000 (·001 c.c.)	10,000 (·0001 c.c.)	100,000 (·00001 c.c.)	4. Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3. Gas. (Gelatine "shake" cultures, 24 hrs. at 20° C.)	Indol. (Broth cultures, 5 days at 37° C.)	(a) Acidity, (b) Clot. (Litmus milk cultures, 5 days at 37° C.) (a)	(b)
23 ..	—	11	8	1902	Effluent from New Leeds Filter (chance sample)				B.S. +	—					+	—		+	+	+	+
24 ..	—	19	8	1902	Effluent from New Leeds Filter (chance sample)					L.P.M. +	—										
25 ..	—	26	8	1902	Effluent from New Leeds Filter (chance sample)											+	—	+	+	+	+
26 ..	—	8	9	1902	Effluent from New Leeds Filter (chance sample)						L.P.M +					+	—	+	+	+	+
27 ..	—	15	9	1902	Effluent from New Leeds Filter (chance sample)												+	+	+	+	+
28 ..	—	22	9	1902	Effluent from New Leeds Filter (chance sample)						B.S. +						+	+	+	+	+
29 ..	—	30	9	1902	Effluent from New Leeds Filter (chance sample)						B.S. + L.P.M.						+	+	+	+	+
30 ..	24 hours	7	10	1902	Effluent from New Leeds Filter						B.S. + L.P.M.						+	+	—	+	+
31 ..	—	13	10	1902	Effluent from New Leeds Filter (chance sample)						B.S. + L.M.P.						+	+	+	+	+
32 ..	—	3	11	1902	Effluent from New Leeds Filter (chance sample)																
33 ..	—	11	11	1902	Effluent from New Leeds Filter (chance sample)																
34 ..	—	25	11	1902	Effluent from New Leeds Filter						B.S. +										
35	—	9	12	1902	Effluent from New Leeds Filter											+	—	+	+	+	+
36 ..	—	31	12	1902	Effluent from New Leeds Filter																
37 ..	—	9	1	1903	Effluent from New Leeds Filter												+	+	—	+	—
38 ..	—	20	1	1903	Effluent from New Leeds Filter																
39 ..	—	10	2	1903	Effluent from New Leeds Filter																

AVERAGES.

Bile salt glucose peptone test:—
1 sample at 100 per c.c.
3 „ „ 1,000 per c.c.
8 „ „ 10,000 per c.c.
60 „ „ 100,000 per c.c.

Lactose peptone milk test :—
1 sample at 100 per c.c.
7 „ „ 10,000 per c.c.
6 „ „ 100,000 per c.c.

3 samples at 1,000 per c.c.
9 „ „ 10,000 per c.c.
8 „ „ 100,000 per c.c.

12 out of 20, indol and clot.
5 out of 20, neither indol nor clot.
1 out of 20, acid clot, but no indol.
2 out of 20, indol, no clot.

THE EFFLUENTS FROM THE NEW LEEDS FILTER—*Continued.*

5						6						7						8						9
Indol Test. Indol in broth cultures direct (5 days at 37° C).						B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						"Gas" Test. "Gas" production in gelatine "shake" cultures, 24 hours at 20° C.						Neutral-red Broth Test. Greenish-yellow fluorescence, 48 hours at 37° C.						REMARKS.
1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	
1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	
			+	—				+	—				24 hrs. +	48 hrs. +	—									
							+	—					24 hrs. +	—	48 hrs. +	—						+	—	
				+	—			+	—				24 hrs. +	—	48 hrs. +	—						+	—	
					+			+	—				24 hrs. +	—	48 hrs. +	—								
					+				+	—				24 hrs. +	48 hrs. +	—							+	
					+			+	—					24 hrs. +	—	48 hrs. +	—							
					+		+	—															+	
				+	—				+	—													+	
					+			+	—														+	
								+	—															Agar at 37° C. 1,000,000 microbes per c.c.
								+	—															Agar at 37° C. 2,500,000 microbes per c.c.
								+	—															
					+			+	—															
								+	—															Agar at 37° C. 320,000 microbes per c.c.
					+		+																	
							+	—																Agar at 37° C. 600,000 microbes per c.c.
								+	—															Agar at 37° C. 1,800,000 microbes per c.c.
1 sample at 100, 5 " " 1,000, 4 " " 10,000, 11 " " 100,000 per c.c.						7 samples at 10, 20 " " 100, 7 " " 1,000 per c.c.						Usually from + ·1 to + ·01 c.c. but more often + ·01 c.c. (24 hours at 20° C.)						2 samples at 1,000, 10 " 10,000, 6 " 100,000 per c.c.						Gelatine at 20° C. 2,875,000; Agar at 370 C. 816,354 microbes per c.c.

RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF THE

1						2						3						4			
Description of the Sample.						B.S. = Bile Salt Glucose Peptone Test (+ = acid and gas). L.P.M. = Lactose Peptone Milk Test (+ = acid gas and clot).						Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method).						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection.				Other Details.													Gas.	Indol	(a) Acidity. (b) Clot.	
	Hour.	Day.	Month.	Year.		1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	(Gelatine "shake" cultures, 24 hrs. at 20° C.)	(Broth cultures, 5 days at 37° C.)	(Litmus milk cultures, 5 days at 37° C.)	
						1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.			(a)	(b)
1 ..	24 hours	7-8	4	1902	Effluent from New Leeds Filter after settlement.										+	—		+	—	+	+
2 ..	24 hours	29	4	1902	Effluent from New Leeds Filter after settlement				B.S. + L.P.	— M.											
3 ..	24 hours	7	5	1902	Effluent from New Leeds Filter after settlement				B.S. +	—											
4 ..	24 hours	15-16	5	1902	Effluent from New Leeds Filter after settlement										+	—		+	+	+	+
5 ..	24 hours	28	5	1902	Effluent from New Leeds Filter after settlement																
6 ..	24 hours	18-19	6	1902	Effluent from New Leeds Filter after settlement											+	—	+	+	+	+
7 ..	—	5	7	1902	Effluent from New Leeds Filter after settlement																
8 ..	—	19	8	1902	Effluent from New Leeds Filter after settlement				L.P. +	M. —											
9 ..	—	8	9	1902	Effluent from New Leeds Filter after settlement					L.P.M. +	—					+	—	+	+	+	+
10 ..	—	15	9	1902	Effluent from New Leeds Filter after settlement										+	—		+	+	+	+
11 ..	—	22	9	1902	Effluent from New Leeds Filter after settlement					B.S. +	—				+	—		+	+	+	+
12 ..	—	30	9	1902	Effluent from New Leeds Filter after settlement						B.S. + L.P.M.						+	+	—	+	+
13 ..	—	6	10	1902	Effluent from New Leeds Filter after settlement						B.S. + L.P.M.						+	+	+	+	+
14 ..	24 hours	23	10	1902	Effluent from New Leeds Filter after settlement			LPM +	B.S. +	—					+	—		+	+	+	+
15 ..	24 hours	30	10	1902	Effluent from New Leeds Filter after settlement																
16 ..	—	4	12	1902	Effluent from New Leeds Filter after settlement																
17 ..	—	13	1	1903	Effluent from New Leeds Filter after settlement				B.S. +	—											
18 ..	—	20	1	1903	Effluent from New Leeds Filter after settlement																
19 ..	—	3	2	1903	Effluent from New Leeds Filter after settlement					B.S. +	—										
20 ..	—	10	2	1903	Effluent from New Leeds Filter after settlement																
21 ..	—	24	3	1903	Effluent from New Leeds Filter after settlement																
AVERAGES						Bile salt glucose peptone test: 4 samples at 1,000 per c.c. 2 " " 10,000 per c.c. 2 " " 100,000 per c.c. Lactose peptone milk test: 1 sample at 100 per c.c. 2 " " 1,000 per c.c. 1 " " 10,000 per c.c. 2 " " 100,000 per c.c.						5 samples at 1,000 per c.c. 2 " " 10,000 per c.c. 2 " " 100,000 per c.c.						7 out of 9, both indol and clot. 2 out of 9, clot, but no indol.			

NEW LEEDS FILTER EFFLUENTS AFTER SETTLEMENT.

5						6						7						8						9
Indol Test. Indol in broth cultures direct (5 days at 37° C).						B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						"Gas" Test. "Gas" production in gelatine "shake" cultures, 24 hours at 20° C.						Neutral-red Broth Test. Greenish-yellow fluorescence, 48 hours at 37° C.						REMARKS.
1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	
1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	
				+	—																			Gelatine at 20° C. 540,000 / Agar at 37° C. 120,000 } microbes per c.c.
							+	—					+	—							+	—		
								+	—			+	—							+	—			
				+	—		+	—													+	—		
								+	—															
			+	—			+	—																
								+	—															
							+	—				24 hrs +	—	48 hours +	—						+	—		
				+	—		+	—					24 hrs. +	48 hours +	—									
			+	—			+	—					24 hrs. +	48 hours +	—							+	—	
			+	—			+	—					24 hrs. +	—	48 hours +	—								
					+			+	—														+	
				+	—			+	—														+	
				+	—			+	—													+	—	
								+	—															Agar at 37° C. 91,000 microbes per c.c.
								+	—															Agar at 37° C. 220,000 microbes per c.c.
								+	—															
							+	—																Agar at 37° C. 260,000 microbes per c.c.
							+	—																
								+	—															Agar at 37° C. 320,000 microbes per c.c.
							+	—																Agar at 37° C. 300,000 microbes per c.c.
3 samples at 1,000 / 5 " " 10,000 / 1 " " 100,000 } per c.c.						10 samples at 10 / 10 " " 100 } per c.c.						Usually + ·1 c.c. (24 hours at 20° C.)						1 sample at 100 / 3 " " 1,000 / 2 " " 10,000 / 2 " " 100,000 } per c.c.						Agar at 37° C. 218,500 microbes per c.c.

RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF THE NEW LEEDS FILTER

1						2						3						4			
Description of the Sample.						B. S.=Bile Salt Glucose Peptone Test (+ = acid and gas). L.P.M.=Lactose Peptone Milk Test (+ = acid gas and clot).						Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method).						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection. Hour.	Day.	Month.	Year.	Other Details.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	Gas. (Gelatine "shake" cultures, 24 hrs. at 20° C.)	Indol. (Broth cultures, 5 days at 37° C.)	(a) Acidity. (b) Clot. (Litmus milk cultures, 5 days at 37° C.) (a)	(b)
1 ..	24 hours	7–8	4	1902	Effluent from New Leeds Filter after filtration								+	—				+	+	+	+
2 ..	24 hours	29	4	1902	Effluent from New Leeds Filter after filtration		B.S. + L.P.	— M.													
3 ..	24 hours	7	5	1902	Effluent from New Leeds Filter after filtration			B.S. — L.P.	M.												
4 ..	24 hours	15–16	5	1902	Effluent from New Leeds Filter after filtration							—									
5 ..	24 hours	28	5	1902	Effluent from New Leeds Filter after filtration																
6 ..	24 hours	18–19	6	1902	Effluent from New Leeds Filter after filtration							—									
7 ..	—	5	8	1902	Effluent from New Leeds Filter after filtration			B.S. +	—												
8 ..	—	11	8	1902	Effluent from New Leeds Filter after filtration				B.S. +	—					+	—		+	+	+	+
9 ..	—	19	8	1902	Effluent from New Leeds Filter after filtration				L.P.M. +	—											
10 ..	—	3	9	1902	Effluent from New Leeds Filter after filtration				B.S. +	—						+	—	+	+	+	+
11 ..	—	15	9	1902	Effluent from New Leeds Filter after filtration											+	—	+	+	+	+
12 ..	—	22	9	1902	Effluent from New Leeds Filter after filtration					B.S. +	—					+	—	+	+	+	+
13 ..	—	30	9	1902	Effluent from New Leeds Filter after filtration.						B.S. + L.P.M.					+	—	+	+	+	+
14 ..	—	6	10	1902	Effluent from New Leeds Filter after filtration.					B.S. + L.P.M.	—					+	—	+	—	+	+
15 ..	24 hours	7	10	1902	Effluent from New Leeds Filter after filtration.				L.P.M. +	B.S. +	—					+	—	+	—	+	—
16 ..	,,	23	10	1902	Effluent from New Leeds Filter after filtration.			B.S. +	—							+	—	+	—	+	—
17 ..	—	27	10	1902	Effluent from New Leeds Filter after filtration.			B.S. +	—												
18 ..	24 hours	30	10	1902	Effluent from New Leeds Filter after filtration.																
19 ..	—	3	11	1902	Effluent from New Leeds Filter after filtration.																
20 ..	—	11	11	1902	Effluent from New Leeds Filter after filtration.																

EFFLUENTS AFTER SETTLEMENT AND FILTRATION THROUGH FINE ASHES.

5						6						7						8						9
Indol Test. Indol in broth cultures direct (5 days at 37° C).						B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anaerobic milk cultures). Cultures heated to 80° C. for 10 minutes.						"Gas" Test. "Gas production in gelatine "shake" cultures, 24 hours at 20° C.						Neutral red Broth Test Greenish-yellow fluorescence, 48 hours at 37° C.						REMARKS.
1 / 1 c.c.	10 / .1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	
	+	—																						Gelatine at 20° C. 390,000 microbes per c.c. Agar at 37° C. 2,500 microbes per c.c.
								+	--			+	—								+	—		
						—						—								—				
—						+	—											+	—					
						+	—																	
—						—																		
							+	—				+	—							—				
			+	—			+	—				24 hrs. +	—	48 hrs. +	—									
							+	—				24 hrs. +	—	48 hrs. +	—							+	—	
				+	—			+	—			24 hrs. +	48 hrs. +	—										
				+	—			+	—					24 hrs. +	48 hrs. +	—							+	
				+	—		+	—						24 hrs. +	48 hrs. +	—								
					+		+	—														+	—	
			+	—			+	—														+	--	
				+	—		+	—													+	—		
				+	—	+	—													+	—			
								+	—															Agar at 37° C. 150,000 microbes per c.c.
							+	—																Agar at 37° C. 173,000 microbes per c.c.
							+	—																Agar at 37° C. 230,000 microbes per c.c.
							+	—																Agar at 37° C. 110,000 microbes per c.c. Cane-sugar test + ·0001; —·00001 c.c.

Results of the Bacteriological Examination of the New Leeds Filter

1						2						3						4			
Description of the Sample.						B. S.=Bile Salt Glucose Peptone Test (+ = acid and gas). L.P.M.=Lactose Peptone Milk Test (+ = acid gas and clot).						Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method).						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection.				Other Details.													Gas.	Indol.	(a) Acidity. (b) Clot. (Litmus milk cultures, 5 days at 37° C.)	
	Hour.	Day.	Month.	Year.		1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	(Gelatine "shake" cultures, 24 hrs. at 20° C.)	(Broth cultures, 5 days at 37° C.)	(a)	(b)
21 ..	24 hours	12	11	1902	Effluent from New Leeds Filter after filtration																
22 ..	—	17	11	1902	Effluent from New Leeds Filter after filtration																
23 ..	—	25	11	1902	Effluent from New Leeds Filter after filtration			B.S. +	—												
24 ..	—	4	12	1902	Effluent from New Leeds Filter after filtration																
25 ..	—	9	12	1902	Effluent from New Leeds Filter after filtration									+	—			+	+	+	
26 .	—	17	12	1902	Effluent from New Leeds Filter after filtration					B.S. +	—										
27 ..	—	31	12	1902	Effluent from New Leeds Filter after filtration																
28 ..	—	9	1	1903	Effluent from New Leeds Filter after filtration										+	—		+	+	+	+
29 ..	—	13	1	1903	Effluent from New Leeds Filter after filtration				B.S. +	—											
30 ..	—	20	1	1903	Effluent from New Leeds Filter after filtration																
31 ..	—	3	2	1903	Effluent from New Leeds Filter after filtration			B.S. —													
32 ..	—	10	2	1903	Effluent from New Leeds Filter after filtration																
33 ..	—	24	3	1903	Effluent from New Leeds Filter after filtration																

AVERAGES:

Bile salt glucose peptone test:
- 1 sample at 10 per c.c.
- 4 „ „ 100 per c.c.
- 3 „ „ 1,000 per c.c.
- 4 „ „ 10,000 per c.c.
- 1 „ „ 100,000 per c.c.
- 2 „ negative 1/100 c.c.

Lactose peptone milk test:
- 1 sample at 10 per c.c.
- 2 „ „ 1,000 per c.c.
- 1 „ „ 10,000 per c.c.
- 1 „ „ 100,000 per c.c.
- 1 „ negative 1/100 c.c

Number of B. Coli:
- 1 sample at 10 per c.c.
- 1 „ „ 100 per c.c.
- 2 „ „ 1,000 per c.c.
- 7 „ „ 10,000 per c.c.
- 2 „ negative 1 c.c.

Biological characters:
- 8 out of 11, both indol and clot.
- 2 out of 11, neither indol nor clot.
- 1 out of 11, clot, no indol.

EFFLUENTS AFTER SETTLEMENT AND FILTRATION THROUGH FINE ASHES—*Continued.*

5						6						7						8						9
Indol Test. Indol in broth cultures direct (5 days at 37° C).						B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						"Gas" Test. "Gas production in gelatine "shake" cultures, 24 hours at 20° C.						Neutral-red Broth Test Greenish-yellow fluorescence, 48 hours at 37° C.						REMARKS.
1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	
1 c.c.	.1 c.c.	·0 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	
								+	—															Agar at 37° C. 180,000 microbes per c.c. Cane sugar test + ·0001; —·00001 c.c.
								+	—															Cane-sugar test + ·0001; — ·00001 c.c.
						+	—																	
								+	—															Agar at 37° C. 230,000 microbes per c.c.
				+	—		+	—																
							+	—																
								+	—															Agar at 37° C. 75,000 microbes per c.c.
			+	—		+	—																	
							+	—																
						+	—																	Agar at 37° C. 15,000 microbes per c.c.
							+	—																
								+	—															Agar at 37° C. 240,000 microbes per c.c.
							+	—																Agar at 37° C. 170,000 microbes per c.c.
1 sample at 10, 3 " " 1,000, 6 " " 10,000, 1 " " 100,000 per c.c.; 2 " negative 1 c.c.						6 samples at 1, 15 " " 10, 9 " " 100 per c.c.; 2 " negative 1 c.c.						Usually + 1; — ·1 c.c. (24 hours at 20° C.)						1 sample at 1, 1 " " 100, 2 " " 1,000, 3 " " 10,000, 1 " " 100,000 per c.c.; 2 " negative 1/100 c.c.						Agar at 37° C. 134,136 microbes per c.c.

RESULTS OF THE BACTERIOLOGICAL EXAMINATION

1						2						3						4			
Description of the Sample.						B. S. = Bile Salt Glucose Peptone Test (+ = acid and gas). L.P.M. = Lactose Peptone Milk Test (+ = acid gas and clot).						Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method).						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection.				Other Details.	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	Gas.	Indol.	(a) Acidity. (b) Clot. (Litmus milk cultures, 5 days at 37° C.)	
	Hour.	Day.	Month.	Year.		1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	(Gelatine "shake" cultures, 24 hrs. at 20° C.)	(Broth cultures, 5 days at 37° C.)	(a)	(b)
1 ..	24 hours	20	2	1902	Effluent from Old Leeds Bed ..										+	—		+	—	+	+
2 ..	24 hours	25	2	1902	Effluent from Old Leeds Bed ..						B.S. +										
3 ..	24 hours	4	3	1902	Effluent from Old Leeds Filter										+	—		+	+	+	+
4 ..	24 hours	12	3	1902	Effluent from Old Leeds Filter											+	—	+	+	+	+
5 ..	12 a.m.–4 p.m.	19	3	1902	Effluent from Old Leeds Filter					B.S. + L.P.M.											
6 ..	—	24	3	1902	Effluent from Old Leeds Filter												+	+	+	+	+
7 ..	—	25	3	1902	Effluent from Old Leeds Filter					B.S. + L.P.M.											
8 ..	2.35 p.m.	3	4	1902	Effluent from Old Leeds Filter, chance sample												+	+	+	+	+
9 ..	24 hours	7–8	4	1902	Effluent from Old Leeds Filter					B.S. + L.P.M.	—										
10 ..	24 hours	14	4	1902	Effluent from Old Leeds Filter											+		+	+	+	+

AVERAGES:

Bile salt glucose peptone test:
3 samples at 10,000 per c.c.
1 " " 100,000 per c.c.

Lactose peptone milk test:
3 samples at 10,000 per c.c.

2 samples at 1,000 per c.c.
2 " " 10,000 per c.c.
2 " " 100,000 per c.c.

5 out of 6, both ind[ol]
and clot.
1 out of 6, clot, but n[o]
indol.

OF THE EFFLUENT FROM THE OLD LEEDS FILTER.

5						6						7						8						
Indol Test. Indol in broth cultures direct (5 days at 37° C).						B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						"Gas" Test. 'Gas" production in gelatine "shake" cultures, 24 hours at 20° C.						Neutral-red Broth Test. Greenish-yellow fluorescence, 48 hours at 37° C.						REMARKS.
1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	
			+	−																				Gelatine at 20° C. 7,200,000 Agar at 37° C. 120,000 microbes per c.c.
							+	−					+	−								+	−	
			+	−																				Gelatine at 20° C. 90,000 Agar at 37° C. 7000 microbes per c.c.
				+	−																			Gelatine at 20° C. 8,500,000 Agar at 37° C. 170,000 microbes per c.c.
								+	−				+	−								+		
					+																			Gelatine at 20° C. 3,300,000 Agar at 37° C. 430,000 microbes per c.c.
								+	−				+	−								+		
					+																			Gelatine at 20° C. 20,000,000 Agar at 37° C. 1,000,000 microbes per c.c.
								+	−					+	−								+	
				+																				Gelatine at 20° C. 15,000,000 Agar at 37° C. 560,000 microbes per c.c.
2 samples at 1,000 " " 10,000 " " 100,000 per c.c.						1 sample at 10 3 " " 100 per c.c.						3 samples + ·1 c.c. 1 " + ·01 c.c.						3 samples at 10,000 1 " " 100,000 per c.c.						Gelatine at 20° C. 9,015,000 Agar at 37° C, 381,167 microbes per c.c.

RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF THE EFFLUENTS FROM NO. 2 (SECONDARY) SMALL MANCHESTER

1						2						3						4			
Description of the Sample.						B.S. = Bile Salt Glucose Peptone Test (+ = acid and gas). L.P.M. = Lactose Peptone Milk Test (+ = acid gas and clot).						Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method).						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection. Hour.	Day.	Month.	Year.	Other Details.	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	Gas. (Gelatine "shake" cultures, 24 hrs. at 20° C.)	Indol. (Broth cultures, 5 days at 37° C.)	(a) Acidity. (Litmus milk cultures, 5 days at 37° C.)	(b) Clot.
						1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.			(a)	(b)
1 ..	—	24	3	1902	Effluent from No. 2 (secondary) small Manchester Bed											+		+	+	+	+
2 ..	—	25	3	1902	Effluent from No. 2 (secondary) small Manchester Bed			B.S. +	L.P.M. +	—											
3 ..	—	5	2	1902	Effluent from No. 2 (secondary) large Manchester Bed, average of two fillings										+			+	+	+	+
4 ..	—	12	2	1902	Effluent from No. 2 (secondary) large Manchester Bed, average of two emptyings											+	—	+	+	+	+
5 ..	—	25	2	1902	Effluent from No. 2 (secondary) large Manchester Bed, average of two fillings										+	—		+	—	—	—
6 ..	—	4	3	1902	Effluent from No. 2 (secondary) large Manchester Bed No. 2, two fillings										+	—		+	+	+	+
7 ..	—	12	3	1902	Effluent from No. 2 (secondary) large Manchester Bed No. 2, two fillings											+	—	+	—	+	+
8 ..	—	24	3	1902	Effluent from No. 2 (secondary) large Manchester Bed									—							
9 ..	—	25	3	1902	Effluent from No. 2 (secondary) large Manchester Bed			L.P.M. +	B.S. +	—											
10 ..	24 hours	7-8	4	1902	Effluent from No. 2 (secondary) large Manchester Bed											+		+	+	+	+
11 ..	—	26	4	1902	Effluent from No. 2 (secondary) large Manchester Bed, chance sample				L.P.M. +	—					+	—		+	+	+	+
12 ..	—	7	5	1902	Effluent from No. 2 (secondary) large Manchester Bed										—						
13 ..	—	12	5	1902	Effluent from No. 2 (secondary) large Manchester Bed, chance sample		L.P.M. +	B.S. +	—				+	—				+	+	+	+
14 ..	24 hours	28	5	1902	Effluent from No. 2 (secondary) large Manchester Bed, two fillings																
15 ..	—	3	6	1902	Effluent from No. 2 (secondary) large Manchester Bed, chance sample					L.P.M. +											
16 ..	—	16	6	1902	Effluent from No. 2 (secondary) large Manchester Bed, chance sample											+	—	+	+	+	—
17 ..	—	18–19	6	1902	Effluent from No. 2 (secondary) large Manchester Bed										+	—		+	+	+	+

BED; NO. 2 (SECONDARY) LARGE MANCHESTER BED; AND NO. 1 (PRIMARY) LARGE MANCHESTER BED.

5						6						7						8						9
Indol Test. Indol in broth cultures direct (5 days at 37° C).						B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						"Gas" Test. "Gas" production in gelatine "shake" cultures, 24 hours at 20° C.						Neutral-red Broth Test. Greenish-yellow fluorescence, 48 hours at 37° C.						REMARKS.
1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	
1 c.c.	·1 c.c.	·0. c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	
				+																				Gelatine at 20° C. 1,400,000 Agar at 37° C. 47,000 } microbes per c.c.
						+	−					+	−								+	−		
			+	−																				Gelatine at 20° C. 400,000 Agar at 37° C. 22,000 } microbes per c.c.
			+	−																				Gelatine at 20° C. 290,00 Agar at 37° C. 22,000 } microbes per c.c.
			+	−																				Gelatine at 20° C. 1,200,000 Agar at 37° C. 44,000 } microbes per c.c.
			−																					Gelatine at 20° C. 410,000 Agar at 37° C. 9,000 } microbes per c.c.
			+	−																				Gelatine at 20° C. 220,000 Agar at 37° C. 27,000 } microbes per c.c.
		−																						Gelatine at 20° C. 3,000 Agar at 37° C. 300 } microbes per c.c.
							+	−				+	−								+	−		
				+																				Gelatine at 20° C. 850,000 Agar at 37° C. 69,000 } microbes per c.c.
			+	−																				
				+	−																			Gelatine at 20° C. 1,300,000 Agar at 37° C. 110,000 } microbes per c.c.
	+	−				−						−								+	−			
							+	−																
							+	−																
			+	−		+	−																	No streptococci found in ·001 c.c. (agar at 37° C.)
			+	−			+	−																

Results of the Bacteriological Examination of the Effluents from No. 2 (Secondary) Small Manchester

1						2						3						4			
Description of the Sample.						B.S. = Bile Salt Glucose Peptone Test (+ = acid and gas). L.P.M. = Lactose Peptone Milk Test (+ = acid gas and clot).						Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method).						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection.				Other Details.													Gas.	Indol.	(a) Acidity. (b) Clot. (Litmus milk cultures, 5 days at 37° C.)	
	Hour.	Day.	Month.	Year.		1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	(Gelatine "shake" cultures, 24 hrs. at 20° C.)	(Broth cultures, 5 days at 37° C.)	(a)	(b)
18 ..	—	1	7	1902	Effluent from No. 2 (secondary) large Manchester Bed, chance sample											+	—	+	+	+	+
19 ..	—	21	7	1902	Effluent from No. 2 (secondary) large Manchester Bed, chance sample																
20 ..	—	19	8	1902	Effluent from No. 2 (secondary) large Manchester Bed, chance sample					L.P.M +	—										
21 ..	—	15	9	1902	Effluent from No. 2 (secondary) large Manchester Bed, chance sample												+	+	—	+	—
22 ..	—	6	10	1902	Effluent from No. 2 (secondary) large Manchester Bed, chance sample						B.S. + L.P.M.						+	+	—	+	—
23 ..	—	20	10	1902	Effluent from No. 2 (secondary) large Manchester Bed, chance sample				L.P.M +	B.S. +	—					+	—	+	+	+	—
24 ..	24 hours	23	10	1902	Effluent from No. 2 (secondary) large Manchester Bed				L.P.M +	B.S. +	—					+	—	+	+	+	+
25 ..	24 hours	12	11	1902	Effluent from No. 2 (secondary) large Manchester Bed																
26 ..	—	17	11	1902	Effluent from No. 2 (secondary) large Manchester Bed, chance sample																
27 ..	—	4	12	1902	Effluent from No. 2 (secondary) large Manchester Bed																
28 ..	—	9	12	1902	Effluent from No. 2 (secondary) large Manchester Bed									+	—			+	+	+	+
29 .	—	17	12	1902	Effluent from No. 2 (secondary) large Manchester Bed						B.S. +										
30 ..	—	13	1	1903	Effluent from No. 2 (secondary) large Manchester Bed					B.S. +	—										
31 ..	—	3	2	1903	Effluent from No. 2 (secondary) large Manchester Bed				B.S. +	—											
32 ..	—	10	2	1903	Effluent from No. 2 (secondary) large Manchester Bed																
33 ..	—	10	3	1903	Effluent from No. 2 (secondary) large Manchester Bed					B.S. +	—										
34 ..	—	24	3	1903	Effluent from No. 2 (secondary) large Manchester Bed																

Bed ; No. 2 (Secondary) Large Manchester Bed and No. 1 (Primary) Large Manchester Bed.—*Continued.*

5						6						7						8						9
Indol Test. Indol in broth cultures direct (5 days at 37° C).						**B. Enteritidis Sporogenes Test.** Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						"Gas" Test. "Gas production in gelatine "shake" cultures, 24 hours at 20° C.						Neutral-red Broth Test Greenish-yellow fluorescence, 48 hours at 37° C.						REMARKS.
1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	
1 c.c.	.1 c.c.	·0 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	
				+	—		+	—						+	—							+	—	
							+	—																
							+	—						24 hrs +	+	48 hrs. —						+	—	
					+		+	—					24 hrs +	48 hrs +	—							+	—	
					+		+	—														+	—	
				+	—		+	—													+	—		
					+		+	—													+	—		
								+	—															Agar at 37° C. 280,000 microbes per c.c. Cane-sugar test + ·0001 ; — ·00001 c.c.
							+	—																Cane-sugar test + ·0001; — ·00001 c.c.
						+	—																	Agar at 37° C. 51,000 microbes per c.c.
			+	—		+	—																	
								+	—															
							+	—																
							+	—																
							+	—																Agar at 37° C. 67,000 microbes per c.c.
							+	—																
							+	—																Agar at 37° C. 37,000 microbes per c.c.

RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF THE EFFLUENTS FROM NO. 2 (SECONDARY) SMALL MANCHESTER

1						2						3						4			
Description of the Sample.						B.S. = Bile Salt Glucose Peptone Test (+ = acid and gas). L.P.M. = Lactose Peptone Milk Test (+ = acid gas and clot).						Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method).						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection.				Other Details.													Gas.	Indol.	(a) Acidity. (b) Clot. (Litmus milk cultures, 5 days at 37° C.)	
	Hour.	Day.	Month.	Year.		1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	(Gelatine "shake" cultures, 24 hrs. at 20° C.)	(Broth cultures, 5 days at 37° C.)	(a)	(b)
35 ..	—	5	2	1902	Effluent from No. 1 (primary) Manchester Bed, average of two fillings											+	—	+	—	+	+
36 ..	—	12	2	1902	Effluent from No. 1 (primary) large Manchester Bed, average of two emptyings											+	—	+	—	+	+
37 ..	—	25	2	1902	Effluent from No. 1 (primary) large Manchester Bed, average of two fillings												+	+	—	+	+
38 ..	—	4	3	1902	Effluent from No. 1 (primary) large Manchester Bed, two fillings										+	—		+	—	+	+
39 ..	—	12	3	1902	Effluent from No. 1 (primary) large Manchester Bed, two fillings											+	—	+	+	alk.	—

		2	3	4
AVERAGES :	Effluents from No. 2 (secondary) small Manchester Bed	Only two samples were examined		
	Effluents from No. 2 (secondary) large Manchester Bed	Bile salt glucose peptone test : 1 sample at 100 per c.c. 2 " " 1,000 per c.c. 4 " " 10,000 per c.c. 2 " " 100,000 per c.c. Lactose peptone milk test : 1 sample at 10 per c.c. 1 " " 100 per c.c. 3 " " 1,000 per c.c. 2 " " 10,000 per c.c. 1 " " 100,000 per c.c.	1 sample at 10 per c.c. 1 " " 100 per c.c. 5 " " 1,000 per c.c. 7 " " 10,000 per c.c. 2 " " 100,000 per c.c. 1 " negative 1/100 c.c. 1 " " 1/1,000 c.c.	10 out of 16, indol and clot 3 out of 16, neither indol nor clot 1 out of 16 clot, but no indol 2 out of 16 indol, but no clot
	Effluents from No. 1 (primary) large Manchester Bed.	No samples examined by the above tests	1 sample at 1,000 per c.c. 3 " " 10,000 per c.c. 1 " " 100,000 per c.c.	None of the 5 gave both indol and clot 4 out of 5 gave acid clot, but no indol 1 out of 5 gave indol, but no clot

BED; No. 2 (SECONDARY) LARGE MANCHESTER BED; AND No. 1 (PRIMARY) LARGE MANCHESTER BED—*Continued.*

5						6						7						8						9
Indol Test. Indol in broth cultures direct (5 days at 37° C).						B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						"Gas" Test. "Gas production in gelatine "shake" cultures, 24 hours at 20° C.						Neutral-red Broth Test Greenish-yellow fluorescence, 48 hours at 37° C.						REMARKS.
1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	
1 c.c.	.1 c.c.	·0 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	
				+	—																			Gelatine at 20° C. 4,700,000 } microbes per c.c. Agar at 37° C. 180,000 }
			+	—																				Gelatine at 20° C. 2,400,000 } microbes per c.c. Agar at 37° C. 88,000 }
				+	—																			Gelatine at 20° C. 9,300,000 } microbes per c.c. Agar at 37° C. 400,000 }
				+	—																			Gelatine at 20° C. 1,400,000 } microbes per c.c. Agar at 37° C. 29,000 }
				+	—																			Gelatine at 20° C. 2,100,000 } microbes per c.c. Agar at 37° C. 270,000 } (? B. pyocyaneus present in ·001 c.c.)
1 sample at 10 } per c.c. 8 " " 1,000 } 4 " " 10,000 } 3 " " 100,000 } 1 " negative 1/100 c.c. " 1/1,000 c.c.						3 samples at 1 } per c.c. 17 " " 10 } 2 " " 100 } 1 " negative 1 c.c.												1 sample at 100 } per c.c. 3 " " 1,000 } 4 " " 10,000 }						Gelatine at 20° C. 584,125 } microbes per c.c. Agar at 37° C. 61,525 }
1 sample at 1,000 } per c.c. 4 " " 10,000 }						No samples examined by this test												No samples examined by this test						Gelatine at 20° C. 3,980,000 } microbes per c.c. Agar at 37° C. 193,400 }

RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF THE

1						2						3						4			
Description of the Sample.						B.S. = Bile Salt Glucose Peptone Test (+ = acid and gas). L.P.M. = Lactose Peptone Milk Test (+ = acid gas and clot).						Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method).						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection.				Other Details.	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	Gas. (Gelatine "shake" cultures, 24 hrs. at 20° C.)	Indol. (Broth cultures, 5 days at 37° C.)	(a) Acidity. (b) Clot. (Litmus milk cultures, 5 days at 37° C.)	
	Hour.	Day.	Month.	Year.		1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.			(a)	(b)
1 ..	4.38 p.m.	28	1	1902	Effluent from Ducat Bed, chance sample					B.S. +	—										
2 ..	10 a.m.– 6 p.m.	4	2	1902	Effluent from Ducat Bed ..					B.S. +											
3 ..	10 a.m.– 4 p.m.	12	2	1902	Effluent from Ducat Bed ..				B.S. +	—											
4 ..	9 a.m.– 4.30 p.m.	19	2	1902	Effluent from Ducat Bed ..					B.S. +											
5 ..	9 a.m.	25	2	1902	Effluent from Ducat Bed ..					B.S. +											
6 ..	9 a.m.– 4 p.m.	4	3	1902	Effluent from Ducat Bed ..					B.S. +											
7 ..	9 a.m.– 4 p.m.	12	3	1902	Effluent from Ducat Bed ..					B.S. +											
8 ..	10 a.m.– 4 p.m.	19	3	1902	Effluent from Ducat Bed ..									+	—			+	+	+	+
9 ..	—	24	3	1902	Effluent from Ducat Bed ..										+	—		+	+	+	+
10 ..	—	25	3	1902	Effluent from Ducat Bed ..				B.S. + L.P.M	—											
11 ..	2.32 p.m.	3	4	1902	Effluent from Ducat Bed, chance sample											+		+	—	+	+
12 ..	24 hours	7–8	4	1902	Effluent from Ducat Bed ..				B.S. + L.P.M	—											
13 ..	24 hours	14	4	1902	Effluent from Ducat Bed ..			LPM +	B.S. +	—											
14 ..	—	26	4	1902	Effluent from Ducat Bed, chance sample				L.P.M +	—					+	—		+	+	+	+
15 ..	24 hours	29	4	1902	Effluent from Ducat Bed ..			B.S. + LPM	—												
16 ..	24 hours	7	5	1902	Effluent from Ducat Bed ..			B.S. + LPM	—												
17 ..	—	12	5	1902	Effluent from Ducat Bed, chance sample			LPM +	B.S. +	—				+	—			+	+	+	+
18 ..	24 hours	15–16	5	1902	Effluent from Ducat Bed ..										+	—		+	+	+	+

EFFLUENTS FROM THE DUCAT CONTINUOUS FILTER AT LEEDS.

5						6						7						8						9
Indol Test. Indol in broth cultures direct (5 days at 37° C).						B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						"Gas" Test. "Gas" production in gelatine "shake" cultures, 24 hours at 20° C.						Neutral-red Broth Test. Greenish-yellow fluorescence, 48 hours at 37° C.						REMARKS.
1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	
							+	–					–								+	–		
							+	–				+	–							+	–			
							+	–				–									+	–		
								+	–			+	–								+	–		
								+	–			+	–								+	–		
							+	–				+	–								+	–		
								+	–					+	–						+	–		
			+	–																				Gelatine at 20° C. 1,200,000 / Agar at 37° C. 32,000 microbes per c.c.
				+																				Gelatine at 20° C. 3,500,000 / Agar at 37° C. 490,000 microbes per c.c.
							+	–				+	–								+	–		
				+																				Gelatine at 20° C. 550,000 / Agar at 37° C. 130,000 microbes per c.c.
							+	–				+	–								+	–		
			+	–				+	–				+	–								+	–	
			+	–																				
								+	–			+	–							+	–			
							+	–				+	–								+	–		
		+	–				v. +	–				+	–								+	–		v. = Culture virulent to guinea-pig.
			+	–				+	–												+	–		

RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF THE

1						2						3						4			
Description of the Sample.						B.S. = Bile Salt Glucose Peptone Test (+ = acid and gas). L.P.M. = Lactose Peptone Milk Test (+ = acid gas and clot).						Number of B. Coli (or closely allied forms) in 1 c.c. Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method).						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection.				Other Details.													Gas.	Indol	(a) Acidity. (b) Clot. Litmus milk cultures, 5 days at 37° C.)	
	Hour.	Day.	Month.	Year.		1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	(Gelatine "shake" cultures, 24 hrs. at 20° C.)	(Broth cultures, 5 days at 37° C.)	(a)	(b)
19 ..	—	27	5	1902	Effluent from Ducat Bed, chance sample												+	+	+	+	—
20 ..	24 hours	28	5	1902	Effluent from Ducat Bed ..																
21 ..	—	3	6	1902	Effluent from Ducat Bed ..				L.P.M +	—											
22 ..	—	10	6	1902	Effluent from Ducat Bed ..				B.S. + L.P.M	—					+	—		+	+	+	+
23 ..	24 hours	11-12	6	1902	Effluent from Ducat Bed ..										+	—		+	+	+	+
24 ..	—	16	6	1902	Effluent from Ducat Bed, chance sample										+	—		+	—	+	—
25 ..	—	18-19	6	1902	Effluent from Ducat Bed ..									+	—			+	+	+	+
26 .	—	1	7	1902	Effluent from Ducat Bed, chance sample									+	—			+	+	+	+
27 .	—	5	7	1902	Effluent from Ducat Bed ..																
28 ..	—	7	7	1902	Effluent from Ducat Bed ..				L.P.M +	B.S. +	—										
29 ..	—	16	7	1902	Effluent from Ducat Bed, chance sample			B.S. +	L.P.M +	—											
30 ..	—	26	8	1902	Effluent from Ducat Bed, chance sample										+	—		+	+	+	+
31 ..	24 hours	3	9	1902	Effluent from Ducat Bed ..					B.S. +	—				+	—		+	+	+	+
32 ..	—	15	9	1902	Effluent from Ducat Bed, chance sample											+	—	+	+	+	+
33 ..	—	30	9	1902	Effluent from Ducat Bed, chance sample					B.S. + L.P.M	—					+	—	+	+	+	+
34 .	24 hours	7	10	1902	Effluent from Ducat Bed ..					B.S. + L.P.M.	—					+	—	+	+	+	+
35 ..	—	13	10	1902	Effluent from Ducat Bed, chance sample			B.S +	—						+	—		+	+	+	+

EFFLUENTS FROM THE DUCAT CONTINUOUS FILTER AT LEEDS—*Continued.*

5						6						7						8						9
Indol Test. Indol in broth cultures direct (5 days at 37° C).						B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						"Gas" Test. "Gas production in gelatine "shake" cultures, 24 hours at 20° C.						Neutral red Broth Test Greenish-yellow fluorescence, 48 hours at 37° C.						REMARKS.
1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	
1 c.c.	·1 c.c.	·0 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	
				+	—		V. +	N.V +	—													+	—	V. = Culture virulent to guinea-pig. N.V. = Culture non-virulent to guinea-pig.
							+	—																
							+	—																
			+	—			—* +	—* +	—			+	—									+	—	—* = Culture pathogenic but not virulent to guinea-pig.
		+	—				+	—																
		+	—				+	—																No streptococci found in ·001 c.c.
		+	—				+	—																
		+	—				+	-				+	—								+	—		
							+	—																
								+	—															No streptococci found in ·1 c.c.
							+	—																
				+	—		+	—					24 hrs. +	48 hrs. +	—							+	—	
			+	—				+	—			24 hrs. +	—	48 hrs. +	—									
				+	—		+	—					24 hrs +	48 hrs. +	—							+	—	
				+	—			+	-														+	
				+	—			+	—													+	—	
			+	—			+	—													+	—		

RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF THE

1						2						3						4			
Description of the Sample.						B.S. = Bile Salt Glucose Peptone Test (+ = acid and gas). L.P.M. = Lactose Peptone Milk Test (+ = acid gas and clot).						Number of B. Coli (or closely allied forms) in 1 c.c. Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method).						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection.				Other Details.													Gas.	Indol	(a) Acidity. (b) Clot. Litmus milk cultures, 5 days at 37° C.)	
	Hour.	Day.	Month.	Year.		1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	(Gelatine "shake" cultures, 24 hrs. at 20° C.)	(Broth cultures, 5 days at 37° C.)	(a)	(b)
36 ..	—	20	10	1902	Effluent from Ducat Bed, chance sample				B.S. +	L.P.M +	—				+	—		+	+	+	+
37 ..	24 hours	23	10	1902	Effluent from Ducat Bed ..				B.S. + L.P.M	—					+	—		+	+	+	—
38 ..	—	27	10	1902	Effluent from Ducat Bed, chance sample					B.S. +	—										
39 ..	—	30	10	1902	Effluent from Ducat Bed ..																
40 ..	24 hours	12	11	1902	Effluent from Ducat Bed ..																
41 ..	—	17	11	1902	Effluent from Ducat Bed, chance sample																
42 ..	—	25	11	1902	Effluent from Ducat Bed ..				B.S +	—											
43 ..	—	4	12	1902	Effluent from Ducat Bed ..																
44 ..	—	17	12	1902	Effluent from Ducat Bed ..				B.S. +	—											
45 ..	—	31	12	1902	Effluent from Ducat Bed ..																
46 ..	—	9	1	1903	Effluent from Ducat Bed ..											+	—	+	+	+	+
47 ..	—	13	1	1903	Effluent from Ducat Bed ..				B.S. +	—											
48 ..	—	4	3	1903	Effluent from Ducat Bed ..																
49 ..	—	10	3	1903	Effluent from Ducat Bed ..				B.S. +	—											
50 ..	—	24	3	1903	Effluent from Ducat Bed ..																
AVERAGES :						Bile salt glucose peptone test: 4 samples at 100, 12 " " 1,000, 11 " " 10,000 per c.c. Lactose peptone milk test: 4 samples at 100, 8 " " 1,000, 3 " " 10,000 per c.c.						4 samples at 100, 11 " " 1,000, 5 " " 10,000, 1 " " 100,000 per c.c.						17 out of 21, indol and clot; 1 out of 21, neither indol nor clot; 1 out of 21, acid clot, but no indol; 2 out of 21, indol, but no clot			

FLUENTS FROM THE DUCAT CONTINUOUS FILTER AT LEEDS—*Continued.*

5						6						7						8						9
Indol Test. Indol in broth cultures direct (5 days at 37° C).						B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						"Gas" Test. "Gas production in gelatine "shake" cultures, 24 hours at 20° C.						Neutral red Broth Test Greenish-yellow fluorescence, 48 hours at 37° C.						REMARKS.
1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	
1 c.c.	.1 c.c.	·0 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	
			+	—			+	—														+	—	
			+	—				+	—													+	—	
								+	—															Agar at 37° C. 150,000 microbes per c.c.
								+	—															Agar at 37° C. 240,000 microbes per c.c.
								+	—															Agar at 37° C. 8,200 microbes per c.c. Cane-sugar test + ·001 ; — ·0001 c.c.
								+	—															Cane-sugar test + ·0001 ; — ·00001 c.c.
								+	—															
								+	—															Agar at 37° C. 170,000 microbes per c.c.
							+	—																
									+	—														Agar at 37° C. 13,000 microbes per c.c.
				+	—		+	—																
								+	—															
								+	—															Agar at 37° C. 2,700 microbes per c.c.
								+	—															
								+	—															Agar at 37° C. 6,500 microbes per c.c.
5 sample at 100 / 9 " " 1,000 / 8 " " 10,000 } per c.c.						22 samples at 10 / 23 " " 100 / 1 " " 1,000 } per c.c.						Usually + 1 c.c. ; — ·1 c.c. (24 hours at 20° C.)						2 samples at 100 / 13 " " 1,000 / 8 " " 10,000 / 1 " " 100,000 } per c.c.						Gelatine at 20° C. 1,750,000 / Agar at 37° C. 123,740 } microbes per c.c.

RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF

1						2						3						4			
Description of the Sample.						B.S. = Bile Salt Glucose Peptone Test (+ = acid and gas). L.P.M. = Lactose Peptone Milk Test (+ = acid gas and clot).						Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method).						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection. Hour.	Day.	Month.	Year.	Other Details.	1 (1 c.c.)	10 (·1 c.c.)	100 (·01 c.c.)	1,000 (·001 c.c.)	10,000 (·0001 c.c.)	100,000 (·00001 c.c.)	1 (1 c.c.)	10 (·1 c.c.)	100 (·01 c.c.)	1,000 (·001 c.c.)	10,000 (·0001 c.c.)	100,000 (·00001 c.c.)	Gas. (Gelatine "shake" cultures, 24 hrs. at 20° C.)	Indol (Broth cultures, 5 days at 37° C.)	(a) Acidity. (Litmus milk cultures, 5 days at 37° C.) (a)	(b) Clot. (b)
1 ..	10 a.m.–6 p.m.	4	2	1902	Effluent from Cameron Bed ..					B.S. +											
2 ..	10 a.m.–4 p.m.	12	2	1902	Effluent from Cameron Bed ..					B.S. +											
3 ..	9 a.m.–4.30 p.m.	19	2	1902	Effluent from Cameron Bed ..					B.S. +											
4 ..	9 a.m.–4 p.m.	25	2	1902	Effluent from Cameron Bed ..					B.S. +											
5 ..	9 a.m.–4 p.m.	4	3	1902	Effluent from Cameron Bed ..					B.S. +											
6 ..	10 a.m.–4 p.m.	19	3	1902	Effluent from Cameron Bed										+	—		+	+	+	+
7 ..	—	3	4	1902	Effluent from Cameron Bed, taken during full discharge											+		+	+	+	+
8 ..	24 hours	7–8	4	1902	Effluent from Cameron Bed ..					B.S. + L.P.M.	—										
9 ..	24 hours	14	4	1902	Effluent from Cameron Bed ..					B.S. + L.P.M.	—										
10 ..	24 hours	7	5	1902	Effluent from Cameron Bed ..											+	—	+	—	alkali	—
11 ..	24 hours	15–16	5	1902	Effluent from Cameron Bed ..									+	—			+	+	+	+
12 ..	—	27	5	1902	Effluent from Cameron Bed (chance)											+	—	+	+	+	+
13 ..	—	10	6	1902	Effluent from Cameron Bed, No. 4 Bed				B.S. +	L.P.M. +	—				+	—		+	+	+	+
14 ..	24 hours	11–12	6	1902	Effluent from Cameron Bed, No. 4 Bed											+	—	+	+	+	+
15 ..	—	7	7	1902	Effluent from Cameron Bed, No. 4 Bed																
16 ..	—	26		1902	Effluent from Cameron Bed, No. 4 Bed										+	—		+	+	+	+

he Effluents from the Cameron Beds at Leeds.

5						6						7						8						9
Indol Test. Indol in broth cultures direct (5 days at 37° C).						B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						"Gas" Test. "Gas production in gelatine "shake" cultures, 24 hours at 20° C.						Neutral-red Broth Test Greenish-yellow fluorescence, 48 hours at 37° C.						REMARKS.
1 1 c.c.	10 .1 c.c.	100 ·0 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	
						+	–						+	–						+	–			
							+	–				+	–									+		
							+	–					+	–								+		
								+	–				+	–								+		
							+	–					+	–								+	–	
				+																				Gelatine at 20° C. 5,400,000 } microbes per c.c. Agar at 37° C. 55,000
				+																				Gelatine at 20° C. 3,200,000 } microbes per c.c. Agar at 37° C. 130,000
								+	–				+	–									+	
				+	–		+	–					+	–								+	–	
				+	–																			Gelatine at 20° C. 2,600,000 } microbes per c.c. Agar at 37° C. 71,000
				+	–		+	–													+	–		
					+	V. +	N.V. +	–															+	V. = Culture virulent to g. pig. N.V. = Culture non-virulent to guinea pig.
			+	–			V. +	–					+	–								+		
				+	–	+	–																	
							+	–																No streptococci found in ·1, ·01, and ·001 c.c. (agar cultures at 37° C.)
				+	–		+	–					24 hrs. +	–	48 hrs. +	–						+	–	

Results of the Bacteriological Examination of

1						2						3						4			
Description of the Sample.						B.S. = Bile Salt Glucose Peptone Test (+ = acid and gas). L.P.M. = Lactose Peptone Milk Test (+ = acid gas and clot).						Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method).						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection. Hour.	Day.	Month.	Year.	Other Details.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	Gas. (Gelatine "shake" cultures, 24 hrs. at 20° C.)	Indol (Broth cultures, 5 days at 37° C.)	(a) Acidity. (Litmus milk cultures, 5 days at 37° C.)	(b) Clot.
17 ..	24 hours	3	9	1902	Effluent from Cameron Bed. No. 4 Bed						B.S. +						+	+	—	+	+
18 ..	—	30	9	1902	Effluent from Cameron Bed. No. 4 Bed (chance)					B.S. + L.P.M.	—				+	—		+	+	+	—
19 .	—	13	10	1902	Effluent from Cameron Bed. No. 4 Bed (chance).					B.S. + L.P.M.	—					+	—	+	—	+	—
20 ..	—	20	10	1902	Effluent from Cameron Bed. No. 4 Bed (chance)					B.S. + L.P.M.	—					+	—	+	—	+	+
21 ..	—	27	10	1902	Effluent from Cameron Bed. No. 4 Bed (chance)					B.S. +	—										
22 ..	24 hours	12	11	1902	Effluent from Cameron Bed. No. 4 Bed																
23 ..	—	17	12	1902	Effluent from Cameron Bed. No. 4 Bed					B.S. +	—										
24 ..	—	4	3	1903	Effluent from Cameron Bed. No. 1 Bed																
25 ..	—	10	3	1903	Effluent from Cameron Bed. No. 3 Bed					B.S. +	—										

AVERAGES:

Bile salt glucose peptone test:
1 sample at 1,000 per c.c.
13 „ „ 10,000 per c.c.
1 „ „ 100,000 per c.c.

Lactose peptone milk test:
6 samples at 10,000 per c.c.

B. coli test:
1 sample at 100 per c.c.
4 „ „ 1,000 per c.c.
6 „ „ 10,000 per c.c.
1 „ „ 100,000 per c.c.

7 out of 12, indol and clot
2 out of 12, neither indol nor clot
2 out of 12, acid clot, but no indol
1 out of 12, indol, but no clot

E EFFLUENTS FROM THE CAMERON BEDS AT LEEDS.—(*Continued.*)

5						6						7						8						9
Indol Test. Indol in broth cultures direct (5 days at 37° C).						**B. Enteritidis Sporogenes Test.** Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						**"Gas" Test.** "Gas production in gelatine "shake" cultures, 24 hours at 20° C.						**Neutral-red Broth Test** Greenish-yellow fluorescence, 48 hours at 37° C.						**REMARKS.**
1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	
1 c.c.	·1 c.c.	·0 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	
					+			+	−					24 hrs. +	48 hrs. +	−								
			+	−			+	−															+	
				+	−		+	−														+	−	
				+	−			+	−													+	−	
								+	−															Agar at 37° C. 209,000 microbes per c.c.
							+	−																Agar at 37° C. 81,000 microbes per c.c. Cane-sugar test + ·0001; − ·00001 c.c.
						+	−																	
							+	−																Agar at 37° C. 70,000 microbes per c.c.
								+	−															
2 samples at 1,000; 9 " " 10,000; 2 " " 100,000 } per c.c.						3 samples at 1; 13 " " 10; 6 " " 100 } per c.c.						Usually + ·1; − ·01 c.c. (24 hours at 20° C.)						1 sample at 100; 1 " " 1,000; 9 " " 10,000; 3 " " 100,000 } per c.c.						Gelatine at 20° C. 3,733,333; Agar at 37° C. 102,666 } per c.c.

RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF (1) THE WHITTAKER BED EFFLUENTS, AN[D]

1						2						3						4			
Description of the Sample.						B.S. = Bile Salt Glucose Peptone Test (+ = acid and gas). L.P.M. = Lactose Peptone Milk Test (+ = acid gas and clot).						Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method).						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection.				Other Details.													Gas.	Indol.	(a) Acidity. (b) Clot. Litmus milk cultures, 5 days at 37° C.)	
	Hour.	Day.	Month.	Year.		1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	(Gelatine "shake" cultures, 24 hrs. at 20° C.)	(Broth cultures, 5 days at 37° C.)	(a)	(b)
1 ..	4.25 p.m.	28	1	1902	Effluent from No. 2 Whittaker Bed, chance sample				B.S. +	—											
2 ..	10 a.m.–6 p.m.	4	2	1902	Effluent from No. 2 Whittaker Bed					B.S. +	—										
3 ..	10 a.m.–4 p.m.	12	2	1902	Effluent from No. 2 Whittaker Bed				B.S. +	—											
4 ..	9 a.m.–4.30 p.m.	19	2	1902	Effluent from No. 2 Whittaker Bed					B.S. +											
5 ..	9 a.m.–4 p.m.	25	2	1902	Effluent from No. 2 Whittaker Bed					B.S. +											
6 ..	9 a.m.–4 p.m.	4	3	1902	Effluent from No. 2 Whittaker Bed					B.S. +	—										
7 ...	9 a.m.–4 p.m.	12	3	1902	Effluent from No. 2 Whittaker Bed					B.S. +											
8 ..	10 a.m.–4 p.m.	19	3	1902	Effluent from No. 2 Whittaker Bed			LPM +	B.S. +	—											
9 ..	—	24	3	1902	Effluent from No. 2 Whittaker Bed										—						
10 ..	—	25	3	1902	Effluent from No. 2 Whittaker Bed					B.S. + L.P.M.											
11 ..	2.22 p.m.	2	4	1902	Effluent from No. 2 Whittaker Bed, chance sample			B.S. +	L.P.M +	—											
12 ..	24 hours	7-8	4	1902	Effluent from No. 2 Whittaker Bed			B.S + LPM	—												
13 ..	24 hours	14	4	1902	Effluent from No. 2 Whittaker Bed									+	—			+	+	+	+
14 ..	24 hours	29	4	1902	Effluent from No. 2 Whittaker Bed				B.S. + L.P.M	—											
15 ..	24 hours	7	5	1902	Effluent from No. 2 Whittaker Bed			B.S. + LPM	—												
16 ..	—	12	5	1902	Effluent from No. 2 Whittaker Bed, chance sample			B.S. +	L.P.M +	—					+	—		+	—	—	—
17 ..	24 hours	15–16	5	1902	Effluent from No. 2 Whittaker Bed										+	—		+	+	+	+
18 ..	—	27	5	1902	Effluent from No. 2 Whittaker Bed, chance sample										+	—		+	—	—	—
19 ..	24 hours	28	5	1902	Effluent from No. 2 Whittaker Bed																
20 ..	—	3	6	1902	Effluent from No. 2 Whittaker Bed				L.P.M +	—											
21 ..	—	10	6	1902	Effluent from No. 2 Whittaker Bed			B.S. + LPM	—					+	—			+	+	+	+

) THE WHITTAKER BED EFFLUENTS AFTER FILTRATION THROUGH A LAYER OF FINE ASHES.

5						6						7						8						9
Indol Test. Indol in broth cultures direct (5 days at 37° C).						B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						"Gas" Test. "Gas production in gelatine "shake" cultures, 24 hours at 20° C.						Neutral-red Broth Test Greenish-yellow fluorescence, 48 hours at 37° C.						REMARKS.
1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	
1 c.c.	·1 c.c.	·0 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	
							–						+	–								+		
								+	–				+	–							+	–		
								+	–			+	–									+	–	
								+	–				+	–							+	–		
								+	–				+	–								+		
								+	–				+	–								+		
								+	–				+	–							+	–		
								+	–			+	–								+	–		
				+																				Gelatine at 20° C. 420,000, Agar at 37° C. 14,000 } microbes per c.c.
								+	–				+	–								+		
							+	–					+	–								+	–	
								+	–			+	–								+	–		
			+	–																				Gelatine at 20° C. 360,000, Agar at 37° C. 36,000 } microbes per c.c.
								+	–			+	–									+	–	
							+	–				+	–							+	–			
		+	–			*+	–					+	–								+	–		* Culture pathogenic, but not virulent to guinea pig.
				+	–		+	–												+	–			
		+	–					V +	–												+	–		V. = Culture virulent to guinea pig.
							+	–																
								+	–															
			+	–				V. +	–			+	–							+	–			V. = Culture virulent to guinea pig.

RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF (1) THE WHITTAKER BED EFFLUENTS, AND

1						2						3						4			
Description of the Sample.						B.S. = Bile Salt Glucose Peptone Test (+ = acid and gas). L.P.M. = Lactose Peptone Milk Test (+ = acid gas and clot).						Number of B. Coli (or closely allied forms) in 1 c.c. Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method).						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection.				Other Details.	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	Gas. (Gelatine "shake" cultures, 24 hrs. at 20° C.)	Indol. (Broth cultures, 5 days at 37° C.)	(a) Acidity. (b) Clot. (Litmus milk cultures, 5 days at 37° C.)	
	Hour.	Day.	Month.	Year.		1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.			(a)	(b)
22 ..	24 hours	11–12	6	1902	Effluent from No. 2 Whittaker Bed										+	—		+	+	+	+
23 ..	—	16	6	1902	Effluent from No. 2 Whittaker Bed, chance sample										+	—		+	—	+	+
24 ..	—	18–19	6	1902	Effluent from No. 2 Whittaker Bed										+	—		+	+	+	+
25 ..	—	1	7	1902	Effluent from No. 2 Whittaker Bed, chance sample										+	—		+	—	+	
26 ..	—	5	7	1902	Effluent from No 2 Whittaker Bed																
27 ..	—	7	7	1902	Effluent from No. 2 Whittaker Bed				B.S. + L.P.M	—											
28 ..	—	16	7	1902	Effluent from No. 2 Whittaker Bed, chance sample				L.P.M +	B S. +	—										
29 ..	—	21	7	1902	Effluent from No. 2 Whittaker Bed, chance sample																
30 ..	—	5	8	1902	Effluent from No. 2 Whittaker Bed				B.S. +	L.P.M. +	—										
31 ..	—	11	8	1902	Effluent from No. 2 Whittaker Bed, chance sample				B.S. +	—					+	—		+	+	+	+
32 ..	—	8	9	1902	Effluent from No. 2 Whittaker Bed, chance sample						L.P.M. +						+	+	+	+	+
33 ..	—	15	9	1902	Effluent from No. 2 Whittaker Bed, chance sample											+	—	+	+	+	+
34 ..	—	30	9	1902	Effluent from No. 2 Whittaker Bed, chance sample					B.S. + L.P.M.	—					+	—	+	+	+	+
35 ..	—	7	10	1902	Effluent from No. 2 Whittaker Bed					B.S. +	L.P.M. +					+	—	+	+	+	+
36 ..	—	13	10	1902	Effluent from No. 2 Whittaker Bed, chance sample				B.S. + L.P.M	—						+	—	+	—	+	+
37 ..	—	30	10	1902	Effluent from No. 2 Whittaker Bed																
38 ..	—	3	11	1902	Effluent from No. 2 Whittaker Bed, chance sample																
39 ..	—	11	11	1902	Effluent from No. 2 Whittaker Bed, chance sample																
40 ..	—	25	11	1902	Effluent from No. 2 Whittaker Bed				B.S. +	—											
41 ..	—	9	12	1902	Effluent from No. 2 Whittaker Bed										+	—		+	+	+	+
42 ..	—	31	12	1902	Effluent from No. 2 Whittaker Bed																

(2) THE WHITTAKER BED EFFLUENTS AFTER FILTRATION THROUGH A LAYER OF FINE ASHES—*Continued.*

5						6						7						8						9
Indol Test. Indol in broth cultures direct (5 days at 37° C).						B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						"Gas" Test. "Gas production in gelatine "shake" cultures, 24 hours at 20° C.						Neutral-red Broth Test Greenish-yellow fluorescence, 48 hours at 37° C.						REMARKS.
1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	
1 c.c.	.1 c.c.	·0 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	
		+	—				+	—																
		+	—				+	—																
		+	—				+	—																
		+	—					+	—				+	—							+	—		
							+	—																
								+	—															
							+	—																
								+	—															
								+	—				+	—								+	—	
			+	—				+	—			24 hrs. +	—	48 hrs. +	—									
				+	—			+	—				24 hrs. +	—		48 hrs. +	—							
				+	—			+	—				24 hrs. +	—	48 hrs. +	—						+	—	
				+	—			+	—													+	—	
				+	—			+	—														+	
				+	—			+	—													+	—	
							+	—																Agar at 37° C. 110,000 microbes per c.c.
								+	—															Agar at 37° C. 370,000 microbes per c.c.
								+	—															Agar at 37° C. 45,000 microbes per c.c. Cane-sugar test + ·00001 c.c.
							+	—																
			+	—			+	—																
								+	—															Agar at 37° C. 100,000 microbes per c.c.

RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF (1) THE WHITTAKER BED EFFLUENTS, AND

1						2						3						4			
Description of the Sample.						B.S. = Bile Salt Glucose Peptone Test (+ = acid and gas). L.P.M. = Lactose Peptone Milk Test (+ = acid gas and clot).						Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method).						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection.				Other Details.	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	Gas.	Indol	(a) Acidity. (b) Clot. (Litmus milk cultures, 5 days at 37° C.)	
	Hour.	Day.	Month.	Year.		1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	(Gelatine "shake" cultures, 24 hrs. at 20° C.)	(Broth cultures, 5 days at 37° C.)	(a)	(b)
43 ..	—	9	1	1903	Effluent from No. 2 Whittaker Bed										+	—		+	+	+	+
44 ..	—	20	1	1903	Effluent from No 2 Whittaker Bed																
45 ..	—	3	2	1903	Effluent from No. 2 Whittaker Bed					B.S. +	—										
46 ..	—	4	3	1903	Effluent from No. 2 Whittaker Bed																
47 ..	2.28 p.m.	2	4	1902	Effluent from No. 2 Whittaker Bed after secondary filtration, chance sample.				B.S. +	L.P.M +	—										
48 ..	—	5	7	1902	Effluent from No. 2 Whittaker Bed after filtration																
49 ..	—	16	7	1902	Effluent from No. 2 Whittaker Bed after filtration, chance sample			+ LPM	B.S. +	—											
50 ..	—	21	7	1902	Effluent from No. 2 Whittaker Bed after filtration, chance sample																
51 ..	—	5	8	1902	Effluent from No. 2 Whittaker Bed after filtration				B.S. + L.P.M	—											
52 ..	—	11	8	1902	Effluent from No. 2 Whittaker Bed after filtration, chance sample				B.S. +	—				+	—			+	+	+	+
53 ..	—	3	9	1902	Effluent from No. 2 Whittaker Bed after filtration				B.S. +	—					+	—		+	+	+	+
54 ..	—	8	9	1902	Effluent from No. 2 Whittaker Bed after filtration				LP.M +	—						+	—	+	+	+	+
55 ..	—	15	9	1902	Effluent from No. 2 Whittaker Bed after filtration, chance sample											+	—	+	—	+	—
56 ..	—	22	9	1902	Effluent from No. 2 Whittaker Bed after filtration, chance sample					B.S. +	—				+	—		+	+	+	+
57 ..	—	30	9	1902	Effluent from No. 2 Whittaker Bed after filtration, chance sample				B.S. + LP.M	—						+	—	+	—	+	—
58 ..	—	6	10	1902	Effluent from No. 2 Whittaker Bed after filtration, chance sample				B.S. +	L.P.M. +	—				+	—		+	+	+	+
59 ..	—	7	10	1902	Effluent from No. 2 Whittaker Bed after filtration			B.S. + LPM	—						+	—		+	+	+	+
60 ..	—	23	10	1902	Effluent from No. 2 Whittaker Bed after filtration			B.S. +	L.P.M +	—					+	—		+	—	+	+
61 ..	—	27	10	1902	Effluent from No. 2 Whittaker Bed after filtration, chance sample			B.S. +	—												

) THE WHITTAKER BED EFFLUENTS AFTER FILTRATION THROUGH A LAYER OF FINE ASHES—*Continued.*

5						6						7						8						9
Indol Test. **Indol in broth cultures direct (5 days at 37° C).**						B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						"Gas" Test. "Gas production in gelatine "shake" cultures, 24 hours at 20° C.						Neutral-red Broth Test Greenish-yellow fluorescence, 48 hours at 37° C.						REMARKS.
1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	
1 c.c.	·1 c.c.	·0 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	
				+	—			+	—															
								+	—															Agar at 37° C. 120,000 microbes per c.c.
								+	—															
							+	—																Agar at 37° C. 13,000 microbes per c.c.
							+	—					+	—						+	—			
						+	—																	
							+	—																
							+	—																
							+	—				+	—								+	—		
		+	—					+	-			24 hrs. +	—	48 hrs. +	—									
		+	—				+	—				48 hrs. + neg. 24 hrs.	—											
				+	—			+	—				24 hrs. +	—	48 hrs. +	—								
				+	—		+	—				24 hrs. +	—	48 hrs. +	—						+	—		
		+	—			+	—					24 hrs. +	—	48 hrs. +	—									
				+	—	+	—														+	—		
			+	—			+	—														+	—	
			+	—		+	—													+	—			
		+	—			+	—														÷	--		
							+	—																Agar at 37° C. 15,000 microbes per c.c.

RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF (1) THE WHITTAKER BED EFFLUENTS, AND

No.	1. Description of the Sample. Time of Collection. Hour.	Day.	Month.	Year.	Other Details.	2. B.S. = Bile Salt Glucose Peptone Test (+ = acid and gas). L.P.M. = Lactose Peptone Milk Test (+ = acid gas and clot). 1 (1 c.c.)	10 (·1 c.c.)	100 (·01 c.c.)	1,000 (·001 c.c.)	10,000 (·0001 c.c.)	100,000 (·00001 c.c.)	3. Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours at 37° C.) and subsequent surface gelatine plate method). 1 (1 c.c.)	10 (·1 c.c.)	100 (·01 c.c.)	1,000 (·001 c.c.)	10,000 (·0001 c.c.)	100,000 (·00001 c.c.)	4. Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3. Gas. (Gelatine "shake" cultures, 24 hrs. at 20° C.)	Indol. (Broth cultures, 5 days at 37° C.)	(a) Acidity. (b) Clot. (Litmus milk cultures, 5 days at 37° C.) (a)	(b)
62 ..	—	30	10	1902	Effluent from No. 2 Whittaker Bed, sand filtrate																
63 ..	—	3	11	1902	Effluent from No. 2 Whittaker Bed after filtration, chance sample																
64 ..	—	11	11	1902	Effluent from No. 2 Whittaker Bed after filtration, chance sample																
65 ..	—	12	11	1902	Effluent from No. 2 Whittaker Bed after filtration																
66 ..	—	17	11	1902	Effluent from No. 2 Whittaker Bed after filtration, chance sample																
67 ..	—	25	11	1902	Effluent from No. 2 Whittaker Bed after filtration				B.S. +	—											
68 ..	—	4	12	1902	Effluent from No. 2 Whittaker Bed after filtration																
69 ..	—	9	12	1902	Effluent from No. 2 Whittaker Bed after filtration									+	—			+	+	+	+
70 ..	—	17	12	1902	Effluent from No. 2 Whittaker Bed after filtration			B.S. +	—												
71 ..	—	31	12	1902	Effluent from No. 2 Whittaker Bed after filtration																
72 ..	—	9	1	1903	Effluent from No. 2 Whittaker Bed after filtration											+	—	+	+	+	+
73 ..	—	13	1	1903	Effluent from No. 2 Whittaker Bed after filtration			B.S. +	—												
74 ..	—	20	1	1903	Effluent from No. 2 Whittaker Bed after filtration																
75 ..	—	3	2	1903	Effluent from No 2 Whittaker Bed, sand filtrate				B.S. +	—											
76 ..	—	10	2	1903	Effluent from No. 2 Whittaker Bed after filtration																
77 ..	—	4	3	1903	Effluent from No. 2 Whittaker Bed after filtration																
78 ..	—	24	3	1903	Effluent from No. 2 Whittaker Bed after filtration																

AVERAGES:		2	3	4
	Whittaker Bed Effluents:	Bile-salt glucose peptone test: 5 samples at 100 9 „ „ 1,000 10 „ „ 10,000 per c.c. Lactose peptone milk test: 4 samples at 100 7 „ „ 1,000 3 „ „ 10 000 2 „ „ 100 000 per c.c.	2 samples at 100 10 „ „ 1,000 4 „ „ 10000 1 „ „ 100000 per c.c. 1 „ negative $\frac{1}{1000}$ c.c.	12 out of 17, indol and clot 2 out of 17, neither indol nor clot 3 out of 17, acid clot, but no indol
	Whittaker Bed Effluents after filtration:	Bile-salt glucose peptone test: 5 samples at 100 9 „ „ 1,000 1 „ „ 10,000 per c.c. Lactose peptone milk test: 2 samples at 100 4 „ „ 1,000 2 „ „ 10,000 per c.c	2 samples at 100 5 „ „ 1,000 4 „ „ 10,000 per c.c.	8 out of 11, indol and clot 2 out of 11, neither indol nor clot 1 out of 11, acid clot, but no indol

) THE WHITTAKER BED EFFLUENTS AFTER FILTRATION THROUGH A LAYER OF FINE ASHES—*Continued.*

5						6						7						8						9
Indol Test. Indol in broth cultures direct (5 days at 37° C).						**B. Enteritidis Sporogenes Test.** Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						**"Gas" Test.** "Gas production in gelatine "shake" cultures, 24 hours at 20° C.						**Neutral-red Broth Test** Greenish-yellow fluorescence, 48 hours at 37° C.						REMARKS.
1	10	100	1,000	10,00	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,00	100,000	1	10	100	1,000	10,000	100,000	
1 c.c.	.1 c.c.	·0 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	
						+	−																	Agar at 37° C. 11,000 microbes per c c.
							+	−																Agar at 37° C. 140,000 microbes per c.c.
								+	−															Agar at 37° C. 35,000 microbes per c.c. Cane-sugar test + ·001; —·0001 c.c.
							+	−																Agar at 37° C. 26,000 microbes per c.c. Cane-sugar test + ·001; —·0001 c.c.
							+	−																Cane-sugar test + ·01; —·001 c.c.
						+	−																	
						+	−																	Agar at 37° C. 15,000 microbes per c.c.
		+	−				+	−																
						+	−																	
							+	−																Agar at 37° C. 100,000 microbes per c.c.
				+	−		+	−																
							+	−																
						+	−																	Agar at 37° C. 69,000 microbes per c.c.
						+	−																	
							+	−																Agar at 37° C. 2,600 microbes per c.c.
							+	−																Agar at 37° C. 700 microbes per c.c.
						+	−																	Agar at 37° C. 6,700 microbes per c.c.
6 samples at 100 4 „ „ 1,000 8 „ „ 10,000 } per c.c.						1 sample at 1 13 „ „ 10 29 „ „ 100 } per c.c. 1 „ negative $\frac{1}{10}$ c.c.						Varied from + 1 to + ·1 c.c. (24 hours at 20° C.)						3 samples at 100 8 „ „ 1,000 11 „ „ 10,000 1 „ „ 100,000 } per c.c.						Agar at 37° C. 101,000 microbes per c.c.
5 samples at 100 2 „ „ 1,000 4 „ „ 10,000 } per c.c.						12 samples at 1 17 „ „ 10 3 „ „ 100 } per c.c.						With one exception + 1; — ·1 c.c. (24 hours at 20° C.)						2 samples at 100 4 „ „ 1,000 1 „ „ 10,000 } per c.c.						Agar at 37° C. 38,272 microbes per c.c.

LEEDS.

SUMMARY OF RESULTS.*

Crude and Screened Sewage.

Bile-Salt Glucose Peptone Test.

21 Samples.

18 samples (about 86 per cent.) 100,000 (+ ·00001 c.c.)
3 samples (about 14 per cent.) 10,000 (+ ·0001 c.c.)

These results may be shown in a diagram (each dot represents one per cent. of the samples) as follows:—

Bile-Salt Glucose Peptone Test.

about 86 per cent. ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●
100,000 ●●
10,000 ●●●●●●●●●●●●●● about 14 per cent.

Leeds Crude and Screened Sewage.

Lactose Peptone Milk Test.

14 Samples.

11 samples (about 79 per cent.) 100,000 (+ ·00001 c.c.)
3 samples (about 21 per cent.) 10,000 (+ ·0001 c.c.)

These results may be shown in a diagram (each dot represents one per cent. of the samples) as follows:—

Lactose Peptone Milk Test.

about 79 per cent. ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●
100,000 ●●●
10,000 ●●●●●●●●●●●●●●●●●●●●● about 21 per cent.

B. Coli Test.

16 Samples.

11 samples (about 69 per cent.) 100,000 (+ ·00001 c.c.)
5 samples (about 31 per cent.) 10,000 (+ ·0001 c.c.)

These results may be shown in a diagram (each dot represents one per cent. of the samples) as follows:—

B. Coli Test.

about 69 per cent. ●●●●●●●●●●●●●●●●●●●●
100,000 ●●●
10,000 ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●● about 31 per cent.

As regards the biological attributes of the B. coli or coli-like microbes isolated from the samples, about 62 per cent. were, on the basis of the tests employed, typical B. coli.

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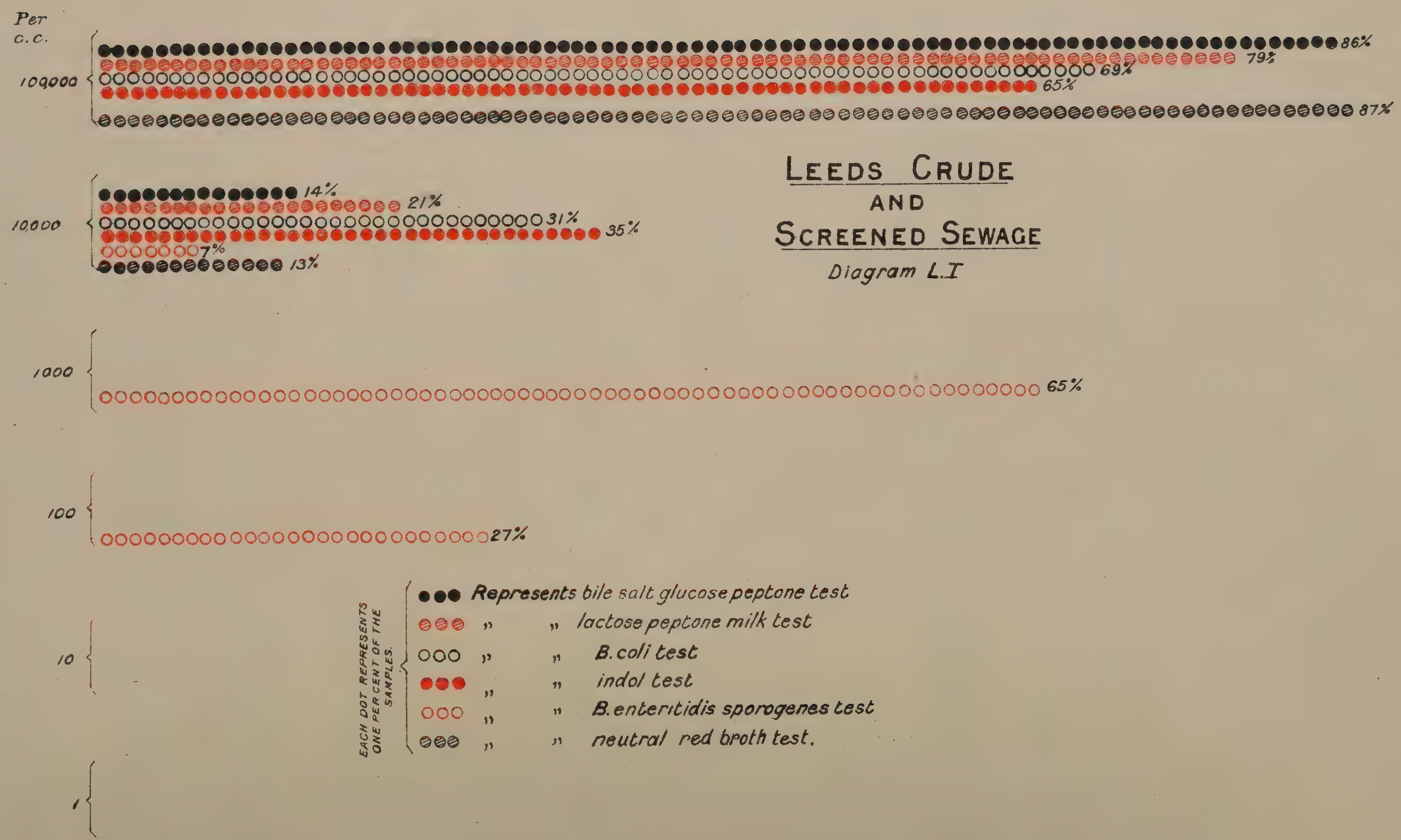
* Unless otherwise stated, the results are given as number of bacteria per c.c. of the sample.

N.B.—As regards the bile-salt glucose peptone, lactose peptone milk, B. coli, and neutral-red broth tests, it is to be noted that the tests were not "pushed" beyond $\frac{1}{100000}$ c.c. It should also be noted that the percentages are frequently based on the examination of a small number of samples. Subject to this qualification, the method adopted of comparing the different results will, it is hoped, be of use to the Commission.



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Crude and Screened Sewage

Indol Test.

17 Samples.

11 samples (about 65 per cent.) 100,000 (+ ·00001 c.c.)
6 samples (about 35 per cent.) 10,000 (+ ·0001 c.c.)

These results may be shown in a diagram (each dot represents one per cent. of the samples) as follows:—

Indol Test

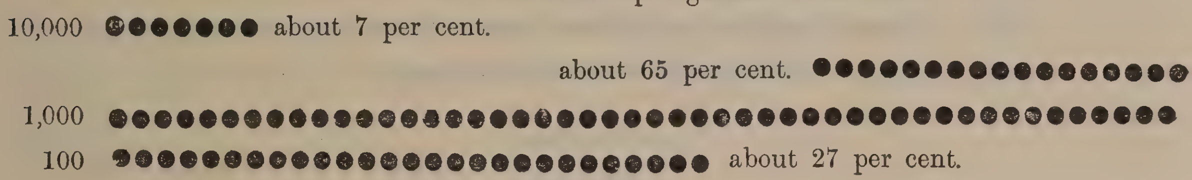
B. Enteritidis Sporogenes Test.

29 Samples.

2 samples (about 7 per cent.) 10,000 (+ ·0001 c.c.)
19 samples (about 65 per cent.) 1,000 (+ ·001 c.c.)
8 samples (about 27 per cent.) 100 (+ ·01 c.c.)

These results may be shown in a diagram (each dot represents one per cent. of the samples) as follows:—

B. Enteritidis Sporogenes.



Crude and Screened Sewage.

"Gas" Test (gas in gelatine "shake" cultures within 24 hours at 20° C.).
18 Samples.

Usually the samples gave a positive result with from + ·01 to + ·001 c.c. within 24 hours at 20° C.

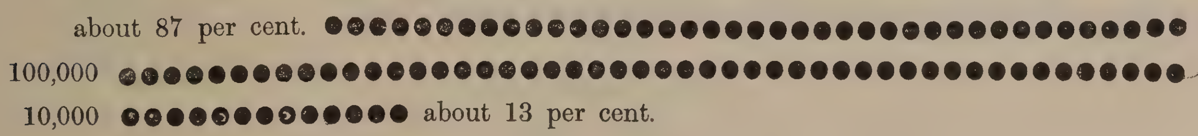
Neutral Red Broth Test.

23 Samples.

20 samples (about 87 per cent.) 100,000 (+ ·00001 c.c.)
3 samples (about 13 per cent.) 10,000 (+ ·0001 c.c.)

These results may be shown in a diagram (each dot represents one per cent. of the samples) as follows:—

Neutral Red Broth Test.



Total Number of Bacteria per c.c.

Gelatine at 20° C.	Agar at 37° C.
39,625,000	2,271,000

Most of the foregoing results may be shown in one diagram for comparative purposes (*see* Diagram L I).

Septic Tank Liquors.

For the sake of simplicity the various tank liquors are considered here together.

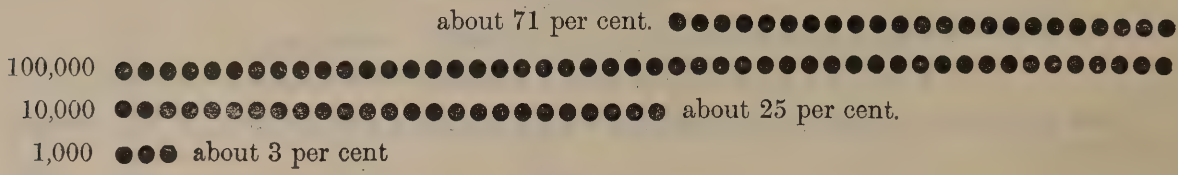
Bile-Salt Glucose Peptone Test.

28 Samples.

20 samples (about 71 per cent.) 100,000 (+ ·00001 c.c.)
7 samples (about 25 per cent.) 10,000 (+ ·0001 c.c.)
1 sample (about 3 per cent.) 1,000 (+ ·001 c.c.)

These results may be shown in a diagram (each dot represents one per cent. of the samples) as follows :—

Bile-Salt Glucose Peptone Test.



Lactose Peptone Milk Test.

12 Samples.

5 samples (about 41 per cent.) 100,000 (+ ·00001 c.c.)
4 samples (about 33 per cent.) 10,000 (+ ·0001 c.c.)
3 samples (about 25 per cent.) 1,000 (+ ·001 c.c.)

These results may be shown in a diagram (each dot represents one per cent. of the samples) as follows :—

Septic Tank Liquors.

Lactose Peptone Milk Test.

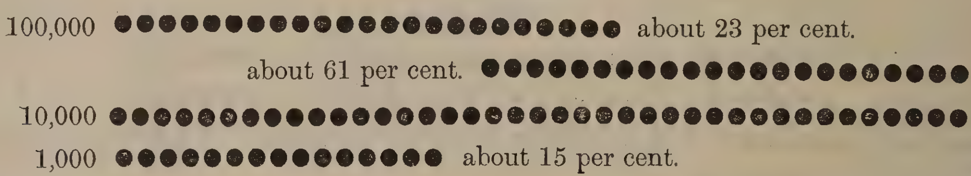
B. Coli Test.

13 Samples.

3 samples (about 23 per cent.) 100,000 (+ ·00001 c.c.)
8 ,, (about 61 per cent.) 10,000 (+ ·0001 c.c.)
2 ,, (about 15 per cent.) 1,000 (+ ·001 c.c.)

These results may be shown in a diagram (each dot represents one per cent. of the samples) as follows :—

B. Coli Test.



As regards the biological character of the B. coli or coli-like microbes isolated from the sample, about 61 per cent. were, on the basis of tests employed, typical B. coli.

Septic Tank Liquors.

Indol Test.

15 Samples.

6 samples (about 40 per cent.) 100,000 (+ ·00001 c.c.)
6 samples (about 40 per cent.) 10,000 (+ ·0001 c.c.)
2 samples (about 13 per cent.) 1,000 (+ ·001 c.c.)
1 sample (about 7 per cent.) negative result $\frac{1}{10000}$ c.c.

These results may be shown in a diagram (each dot represents one per cent. of the samples) as follows :—

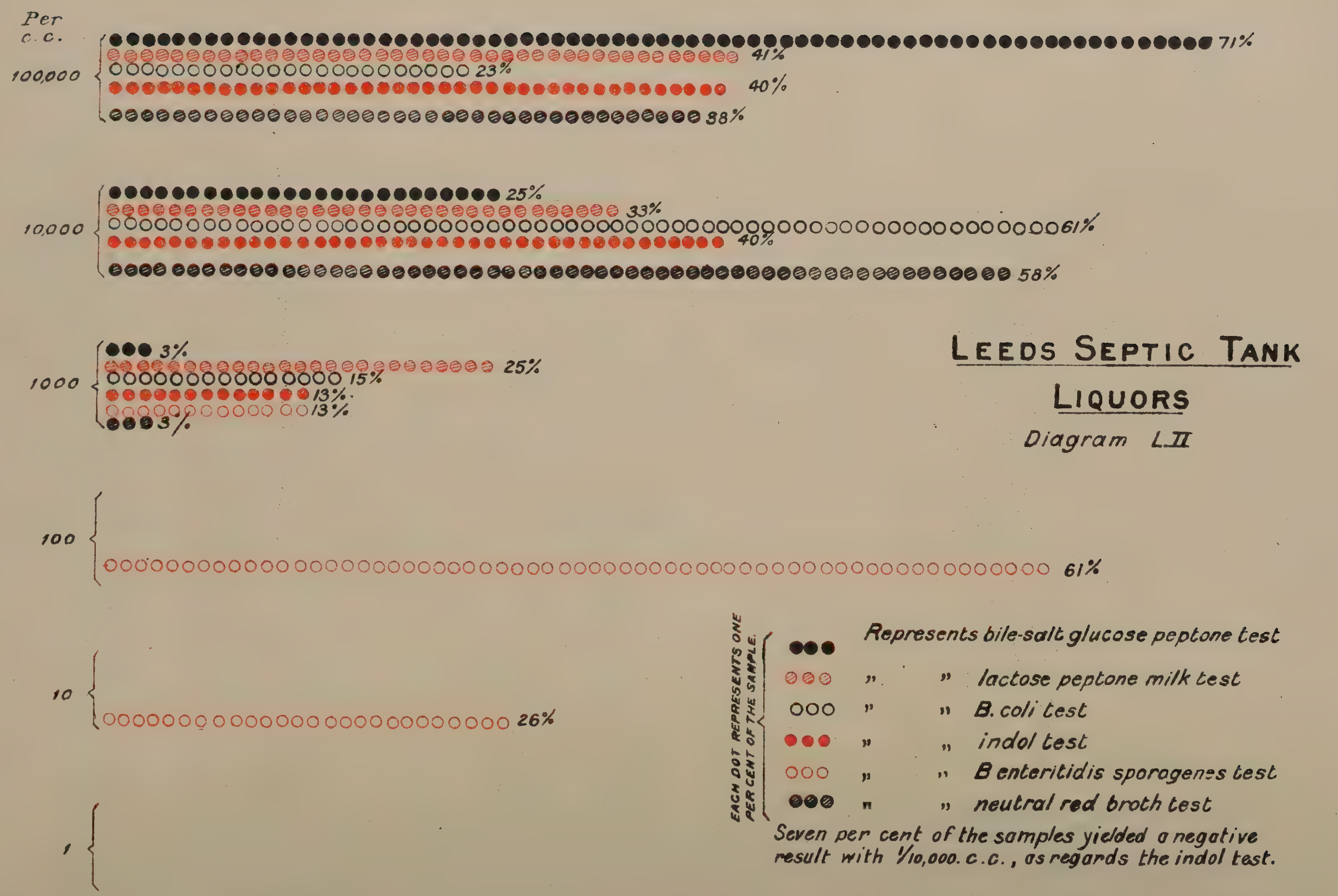
Indol Test.

About 7 per cent. negative $\frac{1}{10000}$ c.c.

LEEDS SEPTIC TANK

LIQUORS

Diagram L.II



Seven per cent of the samples yielded a negative result with 1/10,000. c.c., as regards the indol test.

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B. ENTERITIDIS SPOROGENES TEST.

31 Samples.

4 samples (about 13 per cent.) 1,000 (+ ·001 c.c.)
19 samples (about 61 per cent.) 100 (+ ·01 c.c.)
8 samples (about 26 per cent.) 10 (+ ·1 c.c.)

These results may be shown in a diagram (each dot represents one per cent. of the samples) as follows :—

B. Enteritidis Sporogenes Test.

1,000 ●●●●●●●●●●●●● about 13 per cent.
about 61 per cent. ●●●●●●●●●●●
100 ●●
10 ●●●●●●●●●●●●●●●●●●●●●●●●●● about 26 per cent.

"GAS" TEST (gas in gelatine "shake" cultures within 24 hours at 20° C.)

The results varied usually from + ·1 to + ·01 c.c.

SEPTIC TANK LIQUORS.

NEUTRAL RED BROTH TEST.

29 Samples.

11 samples (about 38 per cent.) 100,000 (+ ·00001 c.c.)
17 samples (about 58 per cent.) 10,000 (+ ·0001 c.c.)
1 sample (about 3 per cent.) 1,000 (+ ·001 c.c.)

These results may be shown in a diagram (each dot represents one per cent. of the samples) as follows :—

Neutral Red Broth Test.

100,000 ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●● about 38 per cent.
about 58 per cent. ●●●●●●●●●
10,000 ●●●
1,000 ●●● about 3 per cent.

TOTAL NUMBER OF BACTERIA PER C.C.

Gelatine at 20° C.	Agar at 37° C.
7,803,636	425,000

Most of the foregoing results may be shown in one diagram for comparative purposes (*see* Diagram L. II).

NEW LEEDS FILTER EFFLUENTS.

Bile-Salt Glucose Peptone Test.

	10.	100.	1,000.	10,000.	100,000.	Negative $\frac{1}{100}$ c.c.
Before settlement -	—	1 s.* (5 per cent.)	3 s. (17 per cent.)	8 s. (44 per cent.)	6 s. (33 per cent.)	—
After settlement -	—	—	4 s. (50 per cent.)	2 s. (25 per cent.)	2 s. (25 per cent.)	—
After settlement and filtration	1 s. (6 per cent.)	4 s. (26 per cent.)	3 s. (20 per cent.)	4 s. (26 per cent.)	1 s. (6 per cent.)	2 s. (13 per cent.)

These results may be shown in a diagram, as follows :—

Bile-Salt Glucose Peptone Test.

33 per cent.
, ,
†100,000 . . . . 25 per cent.
\+ + + + + + 6 per cent.

* S indicates "samples."

† Each sign = one per cent. of the samples : , = before settlement ; . = after settlement ; + = after settlement and filtration.

10,000
44 per cent. , , , , , , , , , , , , , ,
, ,
. . . . 25 per cent.
+ 26 per cent.

1,000
, , , , , , , , , , , , , , , , , 17 per cent.
50 per cent. . . . .
. . . .
+ 20 per cent.

100
, , , , , 5 per cent.
+ 26 per cent.

10
+ + + + + + 6 per cent.

13 per cent. of the samples, after settlement and filtration, yielded a negative result with $\frac{1}{100}$ c.c.

New Leeds Filter Effluents.

Lactose Peptone Milk Test.

	10.	100.	1,000.	10,000.	100,000.	Negative $\frac{1}{100}$ c.c.
Before settlement -	—	1 s. (7 per cent.)*	—	7 s. (50 per cent.)	6 s. (43 per cent.)	—
After settlement -	—	1 s. (16 per cent.)	2 s. (33 per cent.)	1 s. (16 per cent.)	2 s. (33 per cent.)	—
After settlement and filtration - -	1 s. (16 per cent.)	—	2 s. (33 per cent.)	1 s. (16 per cent.)	1 s. (16 per cent.)	1 s. (16 per cent).

These results may be shewn in a diagram, as follows :—

Lactose Peptone Milk Test.

†100,000
43 per cent. , , , , , , , , , ,
, 33 per cent.
. . . .
+ + + + + + + + + + + + + + + + 16 per cent.

10,000
50 per cent. ,
, ,
. . . . 16 per cent.
+ + + + + + + + + + + + + + + + 16 per cent.

1,000
33 per cent.
. . . .
33 per cent.
+ +

* These figures are given for comparative purposes. But percentages based on a few results may be misleading.

† Each sign = one per cent. of the samples ; , = before settlement ; . = after settlement ; + = after settlement and filtration.

, , , , , , , 7 per cent.
100 . . . . 10 per cent.

10 + + + + + + + + + + + + + + + 16 per cent.

16 per cent. of the samples after settlement and filtration yielded a negative result with $\frac{1}{100}$ c.c.

New Leeds Filter Effluents.
B. Coli Test.

	10.	100.	1,000.	10,000.	100,000.	Negative 1 c.c.
Before settlement -	—	—	3 s. (15 per cent.)	9 s. (45 per cent.)	8 s. (40 per cent.)	—
After settlement -	—	—	5 s. (55 per cent.)	2 s. (22 per cent.)	2 s. (22 per cent.)	—
After settlement and filtration	1 s. (7 per cent.)	1 s. (7 per cent.)	2 s. (15 per cent.)	7 s. (54 per cent.)	—	2 s. (15 per cent.)

These results may be shown in a diagram as follows :—

B. Coli Test.

40 per cent. , , , , , , , , ,
*100,000 ,
. . . . 22 per cent.

, 45 per cent.
10,000 . . . . 22 per cent.
54 per cent.
+ +

, , , , , , , , , , , , , , , 15 per cent.
1,000 55 per cent. . . . .
. . . .
+ + + + + + + + + + + + + + + 15 per cent.

100
+ + + + + + + 7 per cent.

10
+ + + + + + + 7 per cent.

15 per cent. of the samples after settlement and filtration yielded a negative result with 1 c.c.

As regards the biological attributes of the B. coli or coli-like microbes isolated from the various samples, 67 per cent. were, on the basis of the tests employed, typical B. coli.

Indol Test.

	10.	100.	1,000.	10,000.	100,000.	Negative 1 c.c.
Before settlement -	—	1 s. (5 per cent.)	5 s. (24 per cent.)	4 s. (18 per cent.)	11 s. (52 per cent.)	—
After settlement -	—	—	3 s. (33 per cent.)	5 s. (55 per cent.)	1 s. (11 per cent.)	—
After settlement and filtration - -	1 s. (8 per cent.)	—	3 s. (23 per cent.)	6 s. (46 per cent.)	1 s. (8 per cent.)	2 s. (15 per cent.)

* Each sign = one per cent. of the samples : , = before settlement ; . = after settlement ; + = after settlement and filtration.

These results may be shown in a diagram as follows:—

NEW LEEDS FILTER EFFLUENTS.

Indol Test.

*100,000 {
52 per cent. ,
, ,
. . . . 11 per cent.
\+ + + + + + + + 8 per cent.

10,000 {
, , , , , , , , , , , , , , , , , , 18 per cent.
55 per cent. . . . . . .
. . . .
\+ 46 per cent

1,000 {
, 24 per cent.
33 per cent. . . .
. . . .
\+ 23 per cent.

100 {
, , , , , 5 per cent.

10 {
\+ + + + + + + + 8 per cent.

15 per cent. of the samples after settlement and filtration yielded a negative result with 1 c.c.

NEW LEEDS FILTER EFFLUENTS.

B. ENTERITIDIS SPOROGENES TEST.

	1.	10.	100.	1,000.	Negative 1 c.c.
Before settlement - - -	—	7 s. (20 per cent.)	20 s. (59 per cent.)	7 s. (20 per cent.)	—
After settlement - - - -	—	10 s. (50 per cent.)	10 s. (50 per cent.)	—	—
After settlement and filtration -	6 s. (18 per cent.)	15 s. (47 per cent.)	9 s. (28 per cent.)		2 s. (6 per cent.)

These results may be shown in a diagram as follows :—

B. Enteritidis Sporogenes Test.

*1,000 {
, 20 per cent.

100 {
59 per cent. , , , , , , , , , ,
, ,
. . . . 50 per cent.
\+ 28 per cent.

* Each sign = one per cent. of the samples : , = before settlement ; . = after settlement ; + = after settlement and filtration.

```
   ⎧, , , , , , , , , , , , , , , , , , , , 20 per cent.
10 ⎨. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 50 per cent.
   ⎩+ + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + + 47 per cent.
   ⎧
 1 ⎨
   ⎩+ + + + + + + + + + + + + + + + + + 18 per cent.
```

6 per cent. of the samples, after settlement and filtration, yielded a negative result with 1 c.c.

"GAS" TEST (gas in gelatine "shake" cultures within 24 hours at 20° C.)

The effluents after settlement yielded better results than before settlement, and the effluents after settlement and filtration better results than before filtration.

NEW LEEDS FILTER EFFLUENTS.

NEUTRAL RED BROTH TEST.

	1.	10.	100.	1,000.	10,000	100,000.	Negative $\frac{1}{100}$ c.c.
Before settlement -	—	- -	—	2 s. (11 per cent.)	10 s. (55 per cent.)	6 s. (33 per cent.)	—
After settlement -	—	—	1 s. (12 per cent.)	3 s. (37 per cent.)	2 s. (25 per cent.)	2 s. (25 per cent.)	—
After settlement and filtration.	1 s. (10 per cent.)	—	1 s. (10 per cent.)	2 s. (20 per cent.)	3 s. (30 per cent.)	1 s. (10 per cent.)	2 s. (20 per cent.)

These results may be shown in a diagram as follows:—

Neutral Red Broth Test.

```
         ⎧, , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , 33 per cent.
*100,000 ⎨. . . . . . . . . . . . . . . . . . . . . . . . . 25 per cent.
         ⎩+ + + + + + + + + + 10 per cent.
         ⎧            55 per cent. , , , , , , , , , , , , , , , , , , , , , , ,
 10,000  ⎨, , , , , , , , , , , , , , , , , , , , , , , , , , , , , , , ,
         ⎪. . . . . . . . . . . . . . . . . . . . . . . . . 25 per cent.
         ⎩+ + + + + + + + + + + + + + + + + + + + + + + + + + + + + + 30 per cent
         ⎧, , , , , , , , , , , 11 per cent.                37 per cent. . . . .
  1,000  ⎨. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
         ⎩+ + + + + + + + + + + + + + + + + + + + 20 per cent.

    100  ⎧. . . . . . . . . . . . 12 per cent.
         ⎩+ + + + + + + + + + + + + + + + + + + + 20 per cent.

     10  ⎧
         ⎩

      1  ⎧
         ⎩+ + + + + + + + + + 10 per cent.
```

20 per cent. of the samples after settlement and filtration yielded a negative result with $\frac{1}{100}$ c.c.

TOTAL NUMBER OF MICROBES (AGAR AT 37° C.) PER C.C.

The average number of bacteria in the effluents before settlement, after settlement, and after both settlement and filtration, was 816,334, 218,500, and 134,136, respectively.

---

* Each sign = one per cent. of the samples: , = before settlement; . = after settlement; + = after settlement and filtration.

For the purposes of a broad comparison with the other effluents and with the sewage and tank liquors, it may be permissible to present the chief New Leeds filter results in one diagram (L.III) without any distinction being drawn between the effluents before settlement and after settlement, and after both settlement and filtration. Following this diagram, however, two other diagrams (L.IV and L.V) are given, showing the results (*a*) before settlement and filtration (L.IV), and (*b*) after both settlement and filtration (L.V).*

OLD LEEDS FILTER EFFLUENTS.

As not many samples were examined, the results may be shown best in a table a follows :—

	10.	100.	1,000.	10,000.	100,000
Bile-salt glucose peptone test -	—	—	—	3 s.†	1 s.
Lactose peptone milk test - - -	—	—	—	3 s.	—
B. coli test - - - - -	—	—	2 s.	2 s.	2 s.
Indol test - - - - -	—	—	2 s.	2 s.	2 s.
B. enteritidis sporogenes test -	1 s.	s.	—	—	—
Neutral red broth test - - -	—	—	—	3 s.	1 s.

TOTAL NUMBER OF BACTERIA PER C.C.

Gelatine at 20° C.	Agar at 37° C.
9,014,000	381,167

MANCHESTER BED EFFLUENTS.

As only a few samples from the No. 2 (secondary) small Manchester bed and No. 1 (primary) large Manchester bed were examined, attention will be directed only to the effluents from the No. 2 (secondary) large Manchester bed.

BILE-SALT GLUCOSE PEPTONE TEST.

9 Samples.

2 samples (about 22 per cent.) 100,000 (+ ·00001 c.c.)
4 samples (about 44 per cent.) 10,000 (+ ·0001 c.c.)
2 samples (about 22 per cent.) 1,000 (+ ·001 c.c.)
1 sample (about 11 per cent.) 100 (+ ·01 c.c.)

These results may be shown in a diagram (each dot represents one per cent. of the samples) as follows :—

MANCHESTER BED EFFLUENTS.

Bile-salt Glucose Peptone Test.

100,000 ●●●●●●●●●●●●●●●●●●●●●● about 22 per cent.

10,000 ●● about 44 per cent.

1,000 ●●●●●●●●●●●●●●●●●●●●●● about 22 per cent.

100 ●●●●●●●●●●● about 11 per cent.

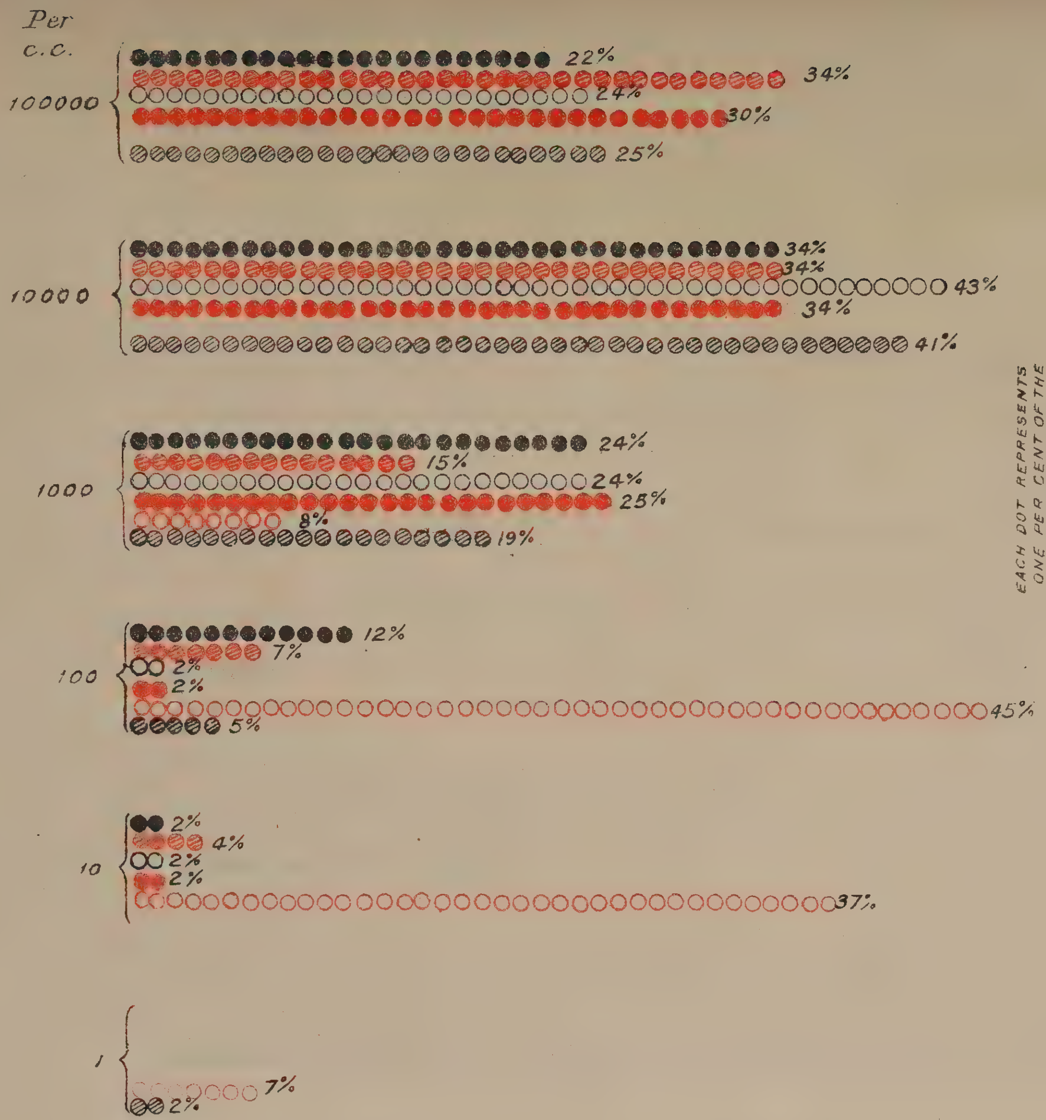
---

* The percentage figures (represented in the diagram by dots) are merely approximate, and are sometimes based on the examination of a small number of samples. They, however, enable the reader to obtain readily some idea of the comparative results yielded by these effluents.

† s. indicates samples.

New Leeds Filter Effluents (inclusive of all the results)

Diagram L.III



EACH DOT REPRESENTS ONE PER CENT OF THE SAMPLES

●●● Represents bile-salt glucose peptone test
" " lactose peptone milk test
" " B. coli test
" " indol test
" " B. enteritidis sporogenes test
" " neutral red broth test

Five, four and five per cent of the samples yielded a negative result with 1/100 c. c. as regards the bile-salt glucose peptone test lactose peptone milk and red broth tests, respectively.

Four, five and two per cent of the samples yielded a negative result with 1 c.c. as regards the B. coli; indol and B. enteritidis sporogenes test respectively.

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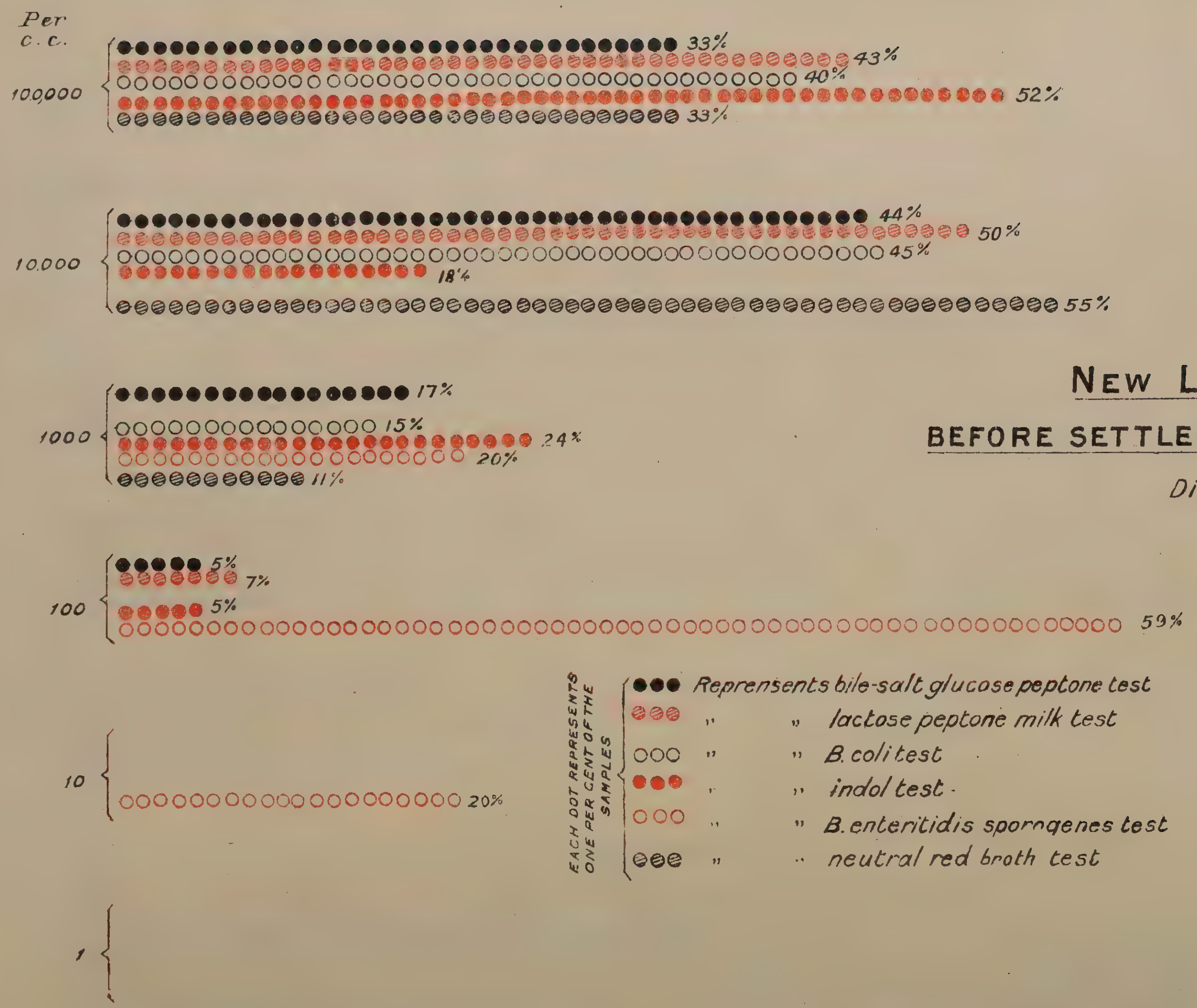
Weller & Graham, Ltd. Litho. London

New Leeds Filter

Before Settlement and Filtration

Diagram L IV



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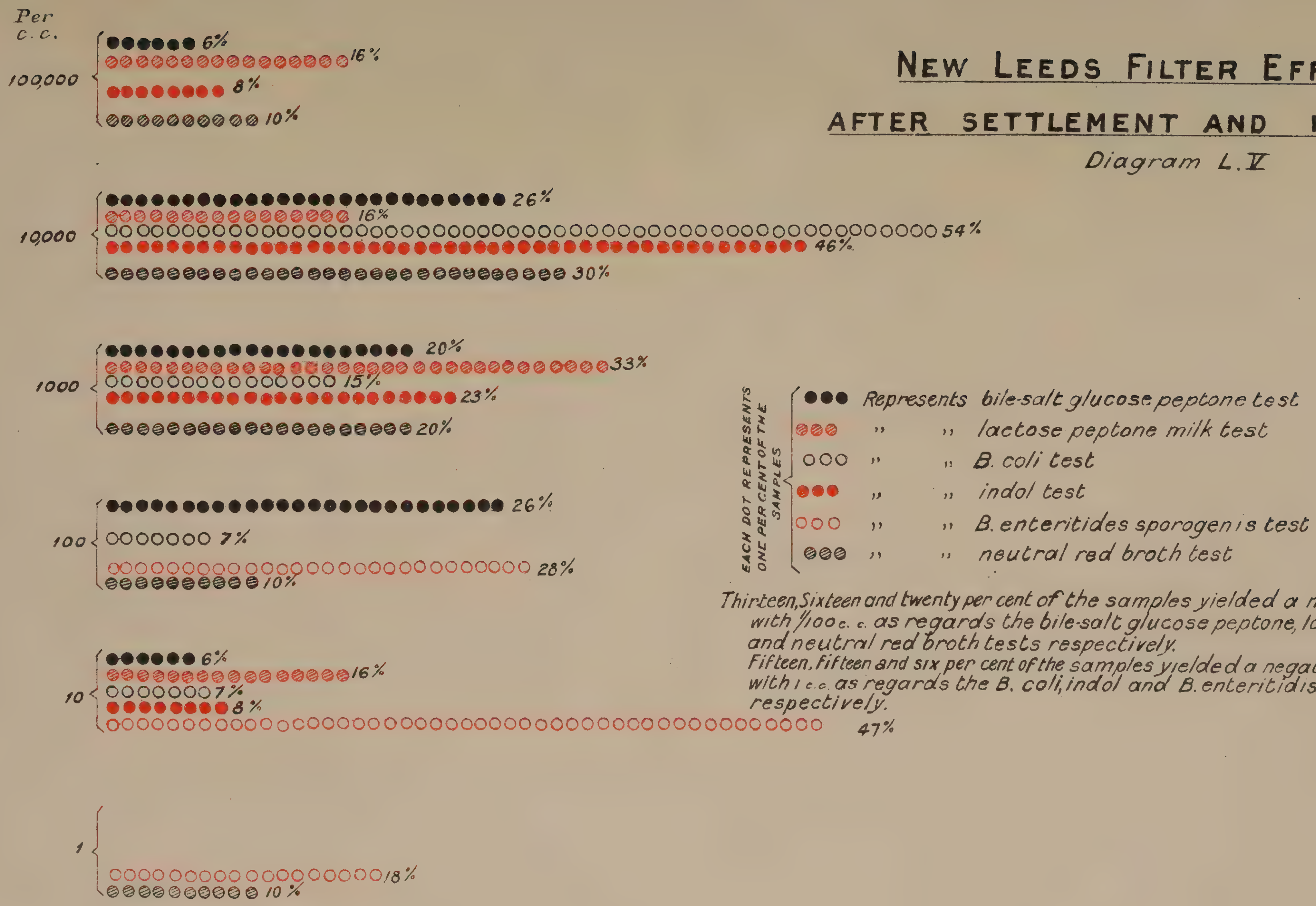
Weller & Graham, Ltd. Litho London.

New Leeds Filter Effluents

After Settlement and Filtration

Diagram L.V



Thirteen, Sixteen and twenty per cent of the samples yielded a negative result with 1/100 c. c. as regards the bile-salt glucose peptone, lactose peptone milk and neutral red broth tests respectively.
Fifteen, fifteen and six per cent of the samples yielded a negative result with 1 c.c. as regards the B. coli, indol and B. enteritidis sporogenes test respectively.

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Walter & Graham L^{td} Litho. London.

Manchester Bed Effluents.

Lactose Peptone Milk Test.

8 Samples.

1 sample	(about 12 per cent.)	100,000	(+ ·00001 c.c.)
2 samples	(about 25 per cent.)	10,000	(+ ·0001 c.c.)
3 samples	(about 37 per cent.)	1,000	(+ ·001 c.c.)
1 sample	(about 12 per cent.)	100	(+ ·01 c.c.)
1 sample	(about 12 per cent.)	10	(+ ·1 c.c.)

These results may be shown in a diagram (each dot represents one per cent. of the samples) as follows:—

Lactose Peptone Milk Test.

100,000 ●●●●●●●●●●●● about 12 per cent.

10,000 ●●●●●●●●●●●●●●●●●●●●●●●●● about 25 per cent.

1,000 ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●● about 37 per cent.

100 ●●●●●●●●●●●● about 12 per cent.

10 ●●●●●●●●●●●● about 12 per cent.

Manchester Bed Effluents.

B. Coli Test.

18 Samples.

2 samples	(about 11 per cent.)	100,000	(+ ·00001 c.c.)
7 samples	(about 39 per cent.)	10,000	(+ ·0001 c.c.)
5 samples	(abont 28 per cent.)	1,000	(+ ·001 c.c.)
1 sample	(about 5 per cent.)	100	(+ ·01 c.c.)
1 sample	(about 5 per cent.)	10	(+ ·1 c.c.)
1 sample	(about 5 per cent.)	negative $\frac{1}{100}$ c.c.	
1 sample	(about 5 per cent.)	negative $\frac{1}{1000}$ c.c.	

These results may be shown in a diagram (each dot represents one per cent. of the sample) as follows:—

B. Coli Test.

100,000 ●●●●●●●●●●● about 11 per cent.

10,000 ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●● about 39 per cent.

1,000 ●●●●●●●●●●●●●●●●●●●●●●●●●●●● about 28 per cent.

100 ●●●●● about 5 per cent.

10 ●●●●● about 5 per cent.

About 5 per cent. negative $\frac{1}{100}$ c.c.

About 5 per cent. negative $\frac{1}{1000}$ c.c.

As regards the biological characters of the B. coli or coli-like microbes isolated from the various samples, it is to be noted that 62 per cent. were, on the basis of the tests employed, typical B. coli.

Manchester Bed Effluents.

Indol Test.

18 Samples.

3 samples	(about 17 per cent.)	100,000	(+ ·00001 c.c.)
4 samples	(about 22 per cent.)	10,000	(+ ·0001 c.c.)
8 samples	(about 44 per cent.)	1,000	(+ ·001 c.c.)
1 sample	(about 5 per cent.)	10	(+ 1 c.c.)
1 sample	(about 5 per cent.)	negative $\frac{1}{100}$ c.c.	
1 sample	(about 5 per cent.)	negative $\frac{1}{1000}$ c.c.	

These results may be shown in a diagram (each dot represents one per cent. of the samples) as follows:

Indol Test.

100,000 ●●●●●●●●●●●●●●●●● about 17 per cent.

10,000 ●●●●●●●●●●●●●●●●●●●●●● about 22 per cent.

about 44 per cent. ●●●●●●●

1,000 ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●

100

10 ●●●●● about 5 per cent.

About 5 per cent. negative $\frac{1}{100}$ c.c.
About 5 per cent. negative $\frac{1}{000}$ c.c.

MANCHESTER BED EFFLUENTS.

B. ENTERITIDIS SPOROGENES TEST.*

23 Samples.

2 samples (about 8 per cent.) 100 (+ ·01 c.c.)
17 samples (about 74 per cent.) 10 (+ ·1 c.c.)
3 samples (about 13 per cent. 1 (+ ·1 c.c.)
1 sample (about 4 per cent.) negative 1 c.c.

These results may be shown in a diagram (each dot represents one per cent. of the samples) as follows:—

B. Enteritidis Sporogenes Test.

100 ●●●●●●●● about 8 per cent.

about 74 per cent. ●●●●●●●●●●●●●●●●●●●●●●●

10 ●●●

1 ●●●●●●●●●●●●● about 13 per cent.

About 4 per cent. negative 1 c.c.

MANCHESTER BED EFFLUENTS.

NEUTRAL RED BROTH TEST.

8 Samples.

4 samples (about 50 per cent.) 10,000 (+ ·0001 c.c.)
3 samples (about 37 per cent.) 1,000 (+ ·001 c.c.)
1 sample (about 12 per cent.) 100 (+ ·01 c.c.)

These results may be shown in a diagram (each dot represents one per cent. of the samples) as follows:—

about 50 per cent. ●●●●

10,000 ●●

1,000 ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●● about 37 per cent.

100 ●●●●●●●●●●●● about 12 per cent.

TOTAL NUMBER OF BACTERIA PER C.C.

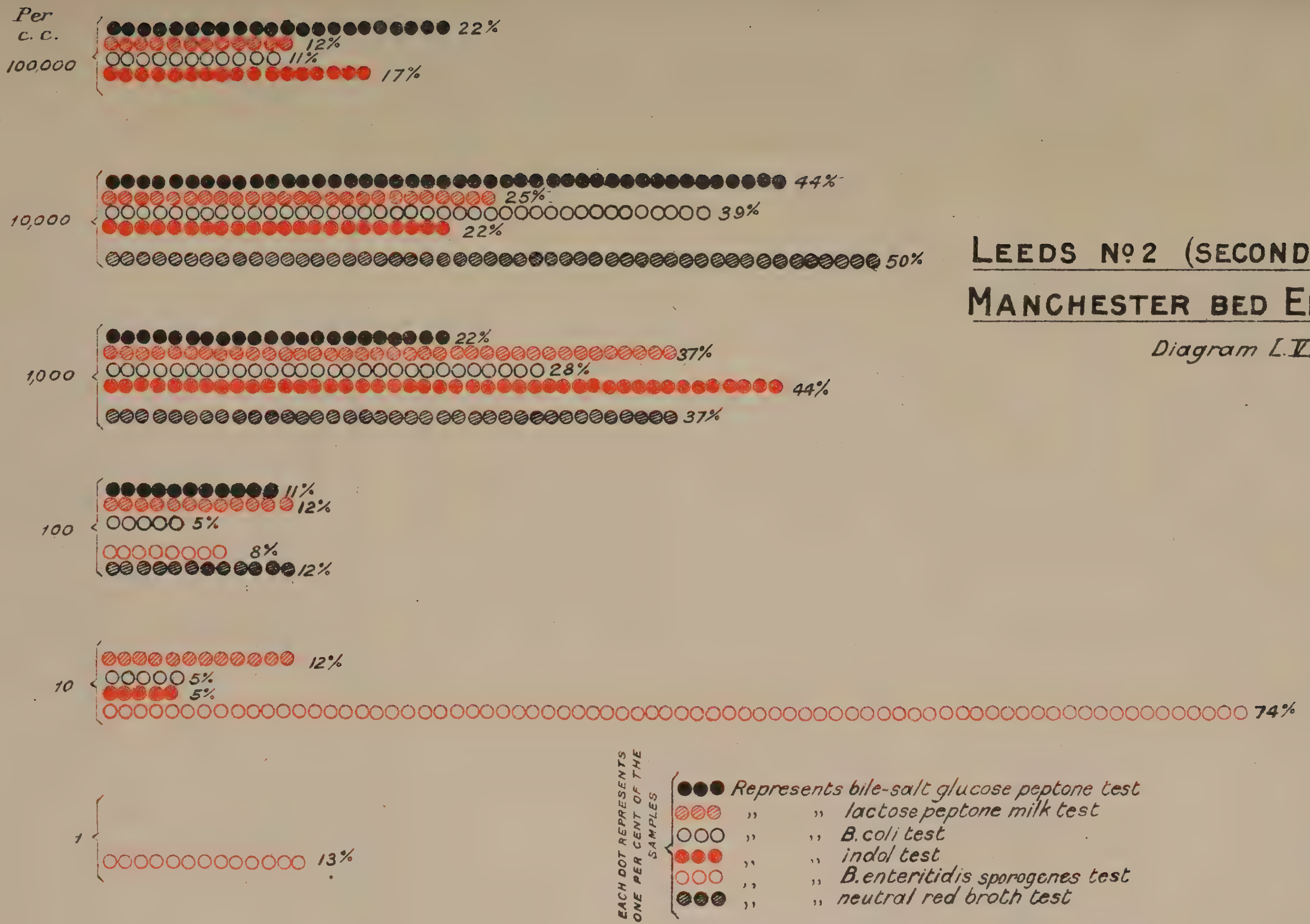
Gelatine at 20° C.	Agar at 37° C.
584,125	61,525

Most of the foregoing results may be shown in one diagram for comparative purposes. (*See* Diagram L. VI.)

* These samples of effluent, for some reason or other, appeared to yield specially good results with the B. enteritidis sporogenes as compared with other tests.

Leeds No. 2 (Secondary) Large Manchester Bed Effluents.

Diagram L.VI



Five per cent of the samples yielded a negative result with 1/100 c. c. as regards both the B. coli and indol tests
Five per cent of the samples yielded a negative result with 1/1000 c. c. as regards both the B coli and indol tests
Four per cent of the samples yielded a negative result with 1 c. c. as regards the B. enteritidis sporogenes test

Waller & Graham, Ld. Litho. London

Ducat Continuous Filter Effluents.

Bile-Salt Glucose Peptone Test.

27 Samples.

11 samples (about 40 per cent.) 10,000 (+ ·0001 c.c.)
12 samples (about 44 per cent.) 1,000 (+ ·001 c.c.)
4 samples (about 15 per cent.) 100 (+ ·01 c.c.)

The results may be shown in a diagram (each dot represents one per cent. of the samples) as follows:—

Bile-Salt Glucose Peptone Test.

10,000 ●● about 40 per cent.
1,000 ●● about 44 per cent.
100 ●●●●●●●●●●●●●●● about 15 per cent.

Ducat Continuous Filter Effluents.

Lactose Peptone Milk Test

15 Samples.

3 samples (about 20 per cent.) 10,000 (+ ·0001 c.c.)
8 samples (about 53 per cent.) 1,000 (+ ·001 c.c.)
4 samples (about 27 per cent.) 100 (+ ·01 c.c.)

These results may be shown in a diagram (each dot represents one per cent. of the samples) as follows:—

Lactose Peptone Milk Test.

10,000 ●●●●●●●●●●●●●●●●●●●● about 20 per cent.
about 53 per cent. ●●●
1,000 ●●
100 ●●●●●●●●●●●●●●●●●●●●●●●●●●● about 27 per cent.

Ducat Continuous Filter Effluents.

B. Coli Test.

21 Samples.

1 sample (about 5 per cent.) 100,000 (+ ·00001 c.c.)
5 samples (about 23 per cent.) 10,000 (+ ·0001 c.c.)
11 samples (about 52 per cent.) 1,000 (+ ·001 c.c.)
4 samples (about 19 per cent.) 100 (+ ·01 c.c.)

These results may be shown in a diagram (each dot represents one per cent. of the samples) as follows:—

B. Coli Test.

100,000 ●●●●● about 5 per cent.
10,000 ●●●●●●●●●●●●●●●●●●●●●●● about 23 per cent.
about 52 per cent. ●●●●●
1,000 ●●●
100 ●●●●●●●●●●●●●●●●●●● about 19 per cent.

As regards the biological attributes of the B. coli or coli-like microbes isolated from the various samples, it is to be noted that about 81 per cent. were, on the basis of the tests employed, typical B. coli.

Ducat Continuous Filter Effluents.

Indol Test.

22 Samples.

8 samples (about 36 per cent.) 10,000 (+ ·0001 c.c.)
9 samples (about 41 per cent.) 1,000 (+ ·001 c.c.)
5 samples (about 22 per cent.) 100 (+ ·01 c.c.)

These results may be shown in a diagram (each dot represents one per cent. of the samples) as follows :—

Indol Test.

10,000 ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●● about 36 per cent.
1,000 ●●● about 41 per cent.
100 ●●●●●●●●●●●●●●●●●●●●●● about 22 per cent.

DUCAT CONTINUOUS FILTER EFFLUENTS.

B. ENTERITIDIS SPOROGENES TEST.*

46 Samples.

1 sample (about 2 per cent.) 1,000 (+ ·001 c.c.)
23 samples (about 50 per cent.) 100 (+ ·01 c.c.)
22 samples (about 48 per cent.) 10 (+ ·1 c.c.)

These results may be shown in a diagram (each dot represents 1 per cent. of the samples) as follows :—

B. Enteritidis Sporogenes Test.

1,000 ●● about 2 per cent.
100 ●● about 50 per cent.
10 ●● about 48 per cent.

"GAS" TEST (gas in gelatine "shake" cultures within 24 hours at 20° C.)
Usually the result was positive with 1 c.c., but negative with ·1 c.c. within 24 hours at 20° C.

DUCAT CONTINUOUS FILTER EFFLUENTS.

NEUTRAL RED BROTH TEST.

24 Samples.

1 sample (about 4 per cent.) 100,000 (+ ·00001 c.c.)
8 samples (about 33 per cent.) 10,000 (+ ·0001 c.c.)
13 samples (about 54 per cent.) 1,000 (+ ·001 c.c.)
2 samples (about 8 per cent.) 100 (+ ·01 c.c.)

These results may be shown in a diagram (each dot represents one per cent. of the samples) as follows :—

Neutral Red Broth Test.

100,000 ●●●● about 4 per cent.
10,000 ●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●● about 33 per cent.
1,000 ●● about 54 per cent.
100 ●●●●●●●● about 8 per cent.

TOTAL NUMBER OF BACTERIA PER C.C.

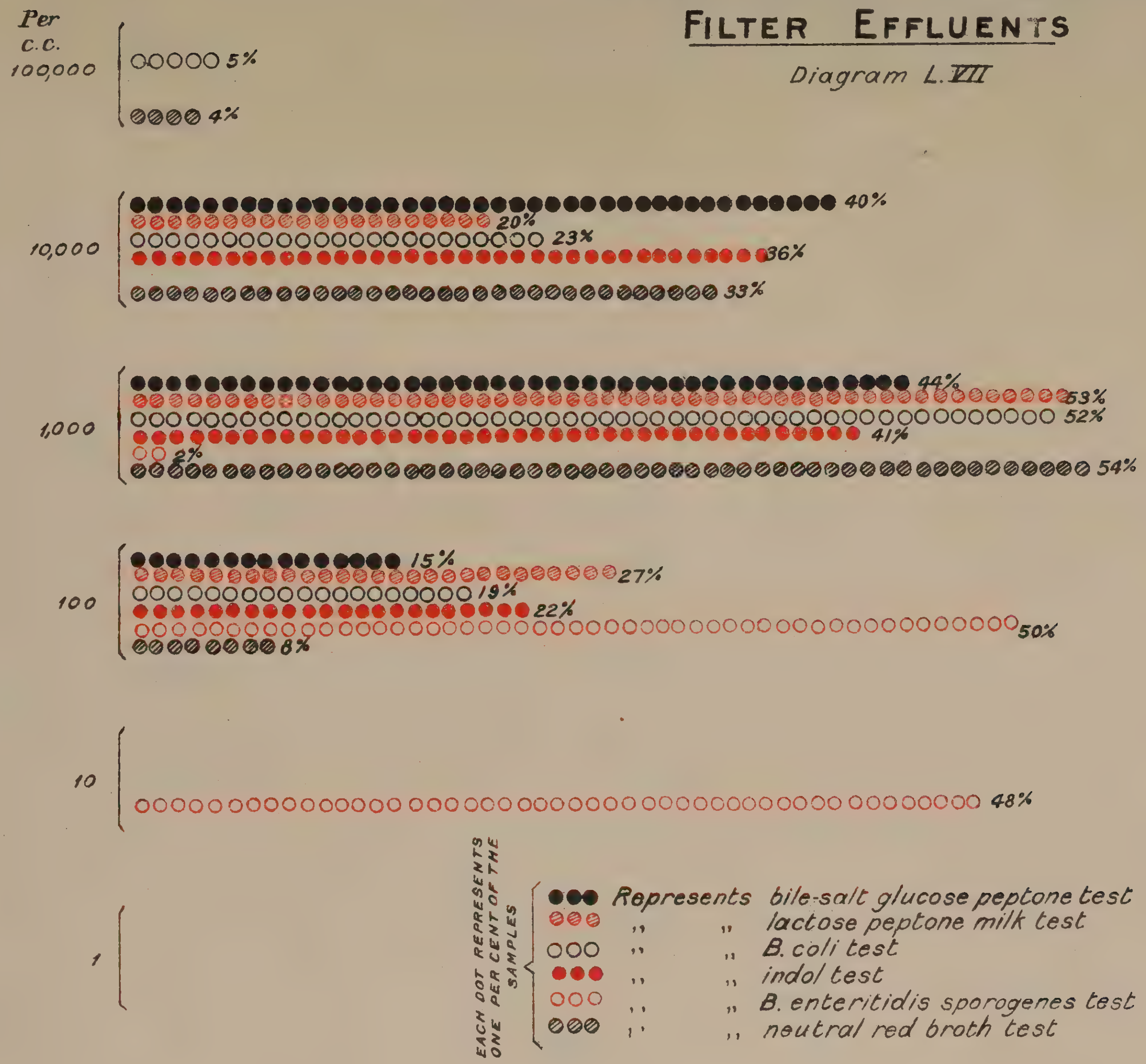
Gelatine at 20° C.	Agar at 37° C.
1,750,000	123,740

Most of the foregoing results may be given in one diagram for comparative purposes. (*See* Diagram L. VII.)

* The effluents, for some reason or other, appeared to be less satisfactory as judged by this test than the results of the other tests might have led the observer to anticipate.

Leeds Ducat Continuous Filter Effluents

Diagram L. VII



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Cameron Bed Effluents

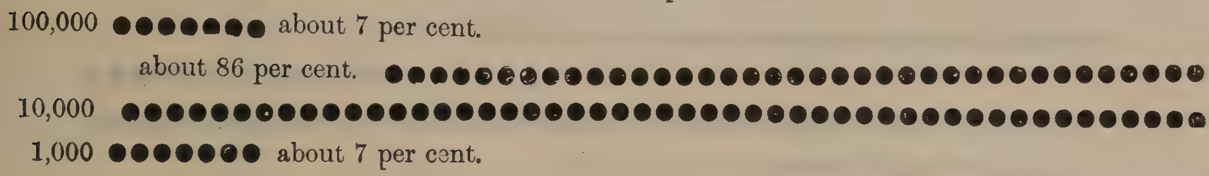
Bile-Salt Glucose Peptone Test.

15 Samples.

1 sample (about 7 per cent.) 100,000 (+ ·00001 c.c.)
13 samples (about 86 per cent.) 10,000 (+ ·0001 c.c.)
1 sample (about 7 per cent.) 1,000 (+ ·001 c.c.)

These results may be shown in a diagram (each dot represents one per cent. of the samples) as follows :—

Bile-Salt Glucose Peptone Test.



Cameron Bed Effluents.

Lactose Peptone Milk Test.

6 Samples.

6 samples (100 per cent.) 10,000 (+ ·0001 c.c.)

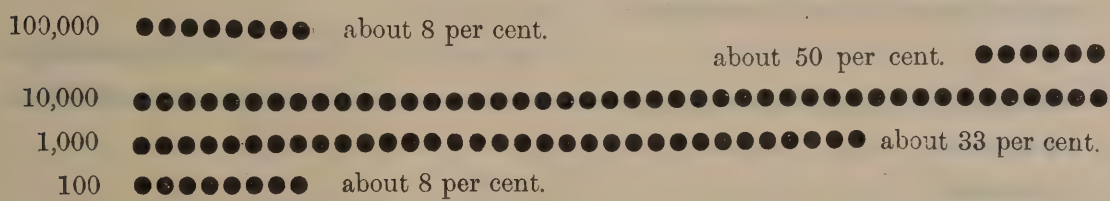
B. Coli Test.

12 Samples.

1 sample (about 8 per cent.) 100,000 (+ ·00001 c.c.)
6 samples (about 50 per cent.) 10,000 (+ ·0001 c.c.)
4 samples (about 33 per cent.) 1,000 (+ ·001 c.c.)
1 sample (about 8 per cent.) 100 (+ ·01 c.c.)

These results may be shown in a diagram (each dot represents one per cent. of the samples) as follows :—

B. Coli Test.



As regards the biological attributes of the B. coli or coli-like microbes isolated from the various samples, about 58 per cent. were, on the basis of the tests employed, typical B. coli.

Cameron Bed Effluents.

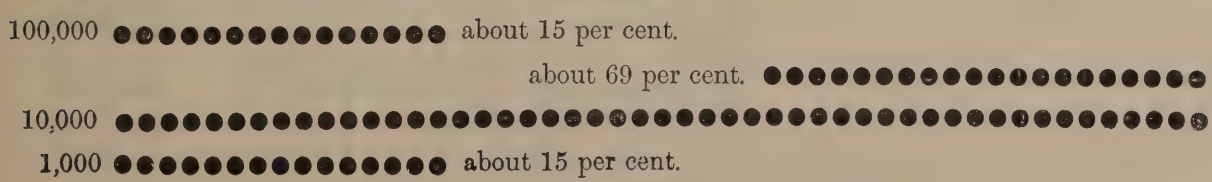
Indol Test.

(13 Samples.)

2 samples (about 15 per cent.) 100,000 (+ ·00001 c.c.)
9 samples (about 69 per cent.) 10,000 (+ ·0001 c.c.)
2 samples (about 15 per cent.) 1,000 (+ ·001 c.c.)

These results may be shown in a diagram (each dot represents one per cent. of the samples) as follows :—

Indol Test.



Cameron Bed Effluents.

B. Enteritidis Sporogenes Test.

22 Samples.

6 samples (about 27 per cent.) 100 (+ ·01 c.c.)
13 samples (about 59 per cent.) 10 (+ ·1 c.c.)
3 samples (about 14 per cent.) 1 (+ 1 c.c.)

These results may be shown in a diagram (each dot represents one per cent. of the samples) as follows:—

B. Enteritidis Sporogenes Test.

100 ●●●●●●●●●●●●●●●●●●●●●●●●●●● about 27 per cent.
about 59 per cent. ●●●●●●●●●●●●●●●
10 ●●
1 ●●●●●●●●●●●●●● about 14 per cent.

"Gas" Test (gas in gelatine "shake" cultures within 24 hours at 20° C.).

Usually the result was + ·1; —·01 c.c. (24 hours at 20° C.).

Cameron Bed Effluents.

Neutral Red Broth Test.

14 Samples.

3 samples (about 21 per cent.) 100,000 (+ ·00001 c.c.)
9 samples (about 64 per cent.) 10,000 (+ ·0001 c.c.)
1 sample (about 7 per cent.) 1,000 (+ ·001 c.c.)
1 sample (about 7 per cent.) 100 (+ ·01 c.c.)

These results may be shown in a diagram (each dot represents one per cent. of the samples) as follows:—

Neutral Red Broth Tests.

100,000 ●●●●●●●●●●●●●●●●●●●●● about 21 per cent.
about 64 per cent. ●●●●●●●●●●●●●●●●
10,000 ●●
1,000 ●●●●●●● about 7 per cent.
100 ●●●●●●● about 7 per cent.

Total Number of Microbes per c.c.

Gelatine at 20° C.	Agar at 37° C.
3,733,333	102,666

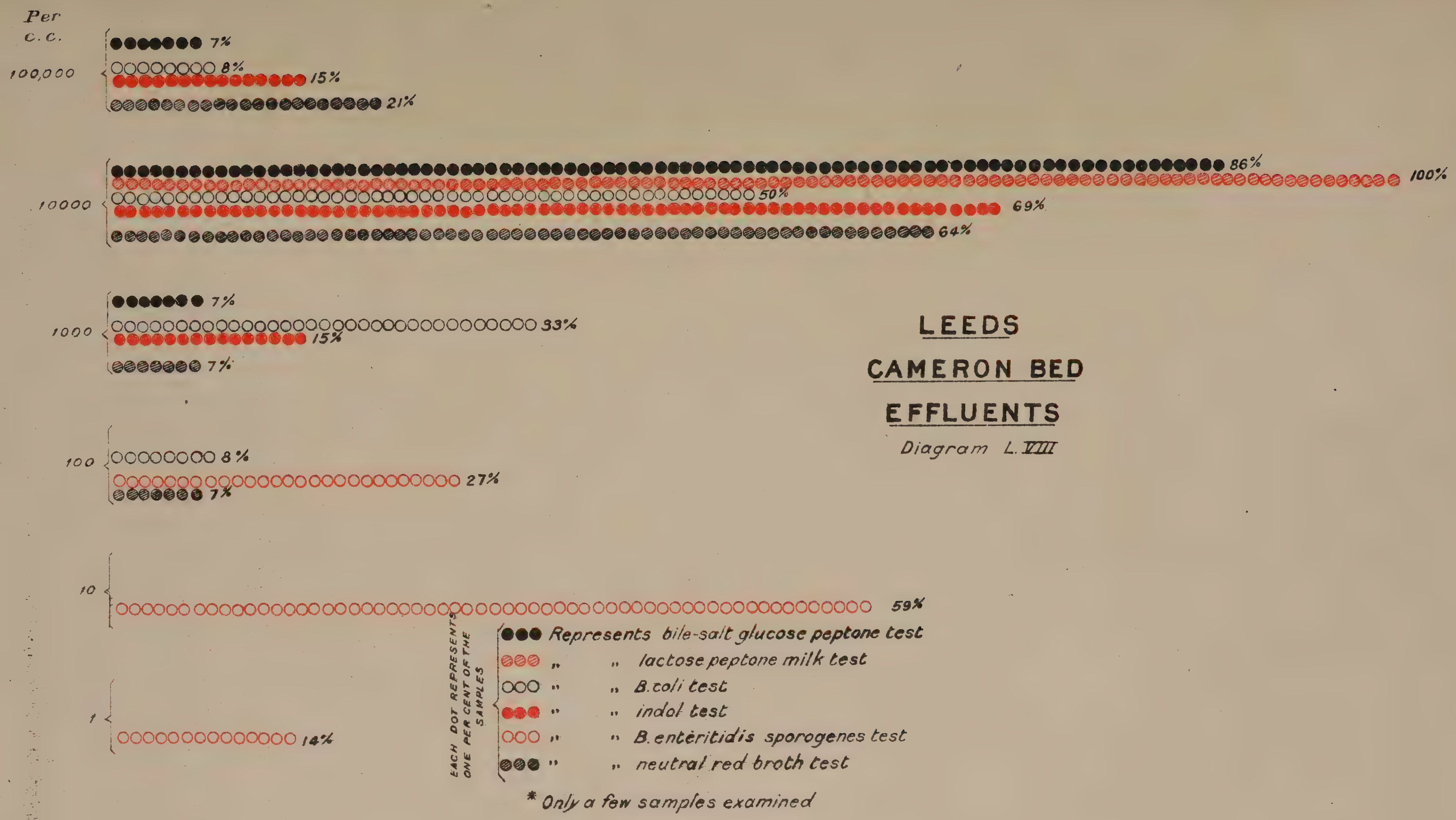
Most of the foregoing results may be shown in one diagram for comparative purposes (*see* Diagram L. VIII).

Whittaker Bed Effluents.

Bile-Salt Glucose Peptone Test.

	100.	1,000.	10,000.
Before filtration - - - - -	5 s.* (20 per cent.)	9 s. (37 per cent.)	10 s. (42 per cent.)
After filtration - - - - -	5 s. (33 per cent.)	9 s. (60 per cent.)	1 s. (7 per cent.)

* s. indicates samples.



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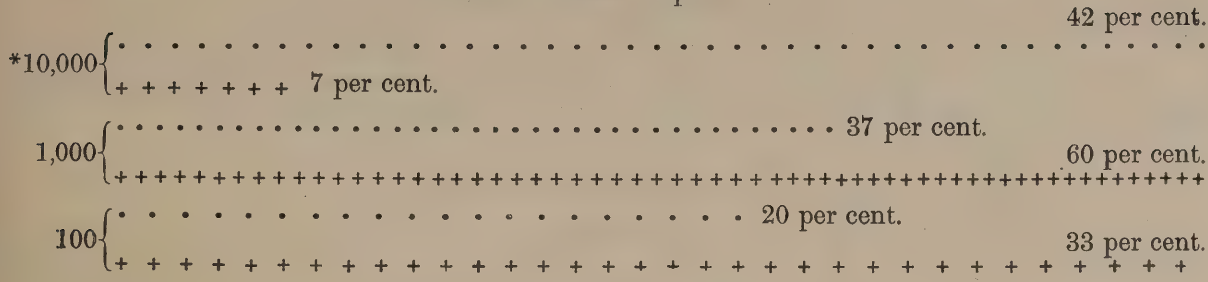
These results may be shown in a diagram as follows:—

Bile-Salt Glucose Peptone Test.



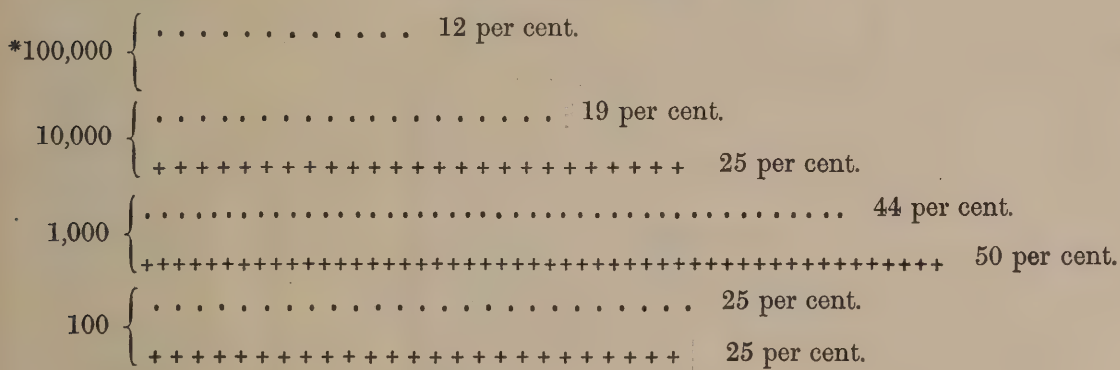
Whittaker Bed Effluents.

Lactose Peptone Milk Test.

	100.	1,000.	10,000.	100,000.
Before filtration - -	4 s. (25 per cent.)	7 s. (44 per cent.)	3 s. (19 per cent.)	2 s. (12 per cent.)
After filtration - -	2 s. (25 per cent.)	4 s. (50 per cent.)	2 s. (25 per cent.)	——

These results may be shown in a diagram, as follows:—

Lactose Peptone Milk Test.



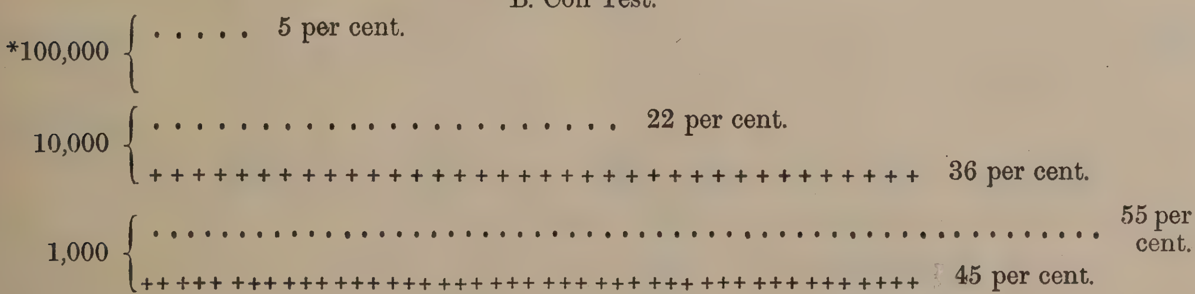
Whittaker Bed Effluents.

B. Coli Test.

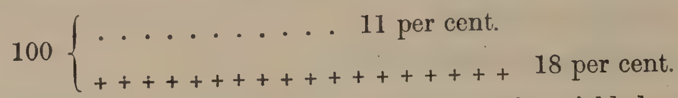
	100	1,000	10,000	100,000	Negative $\frac{1}{1000}$ c.c
Before filtration - - - -	2 s. (11 per cent.)	10 s. (55 per cent.)	4 s. (22 per cent.)	1 s. (5 per cent.)	1 s. (5 per cent.)
After filtration - - - -	2 s. (18 per cent.)	5 s. (45 per cent.)	4 s. (36 per cent.)	—	—

These results may be shown in a diagram, as follows:—

B. Coli Test.



* . = before filtration. + = after filtration. Each sign = one per cent. of the samples.



[5 per cent. of the samples before filtration yielded a negative result with $\frac{1}{1000}$ c.c.]

As regards the biological attributes of the B. coli or coli-like microbes isolated from the various samples, about 71 per cent. were, on the basis of the tests employed, typical B. coli.

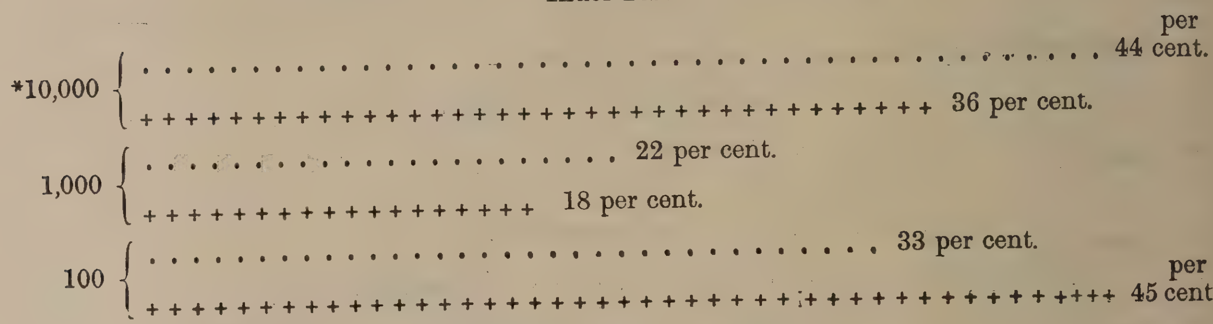
Whittaker Bed Effluents.

Indol Test.

	100	1,000.	10,000.
Before filtration - - - -	6 s. (33 per cent.)	4 s. (22 per cent.)	8 s. (44 per cent.)
After filtration - - - - -	5 s. (45 per cent.)	2 s. (18 per cent.)	4 s. (36 per cent.)

These results may be shown in a diagram, as follows :—

Indol Test.



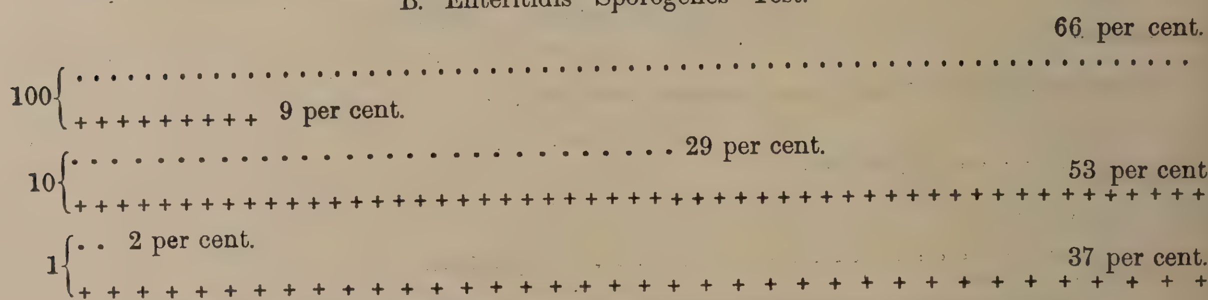
Whittaker Bed Effluents.

B. Enteritidis Sporogenes Test.

	1.	10.	100.	Negative $\frac{1}{10}$ c.c.
Before filtration - -	1 s. (2 per cent.)	13 s. (29 per cent.)	29 s. (66 per cent.)	1 s. (2 per cent.)
After filtration - -	12 s. (37 per cent.)	17 s. (53 per cent.)	3 s. (9 per cent.)	—

These results may be shown in a diagram as follows :—

B. Enteritidis Sporogenes Test.



[2 per cent. of the samples before filtration yielded a negative result with $\frac{1}{10}$ c.c.]

"Gas" Test (gas in gelatine "shake" cultures within 24 hours at 20° C.).

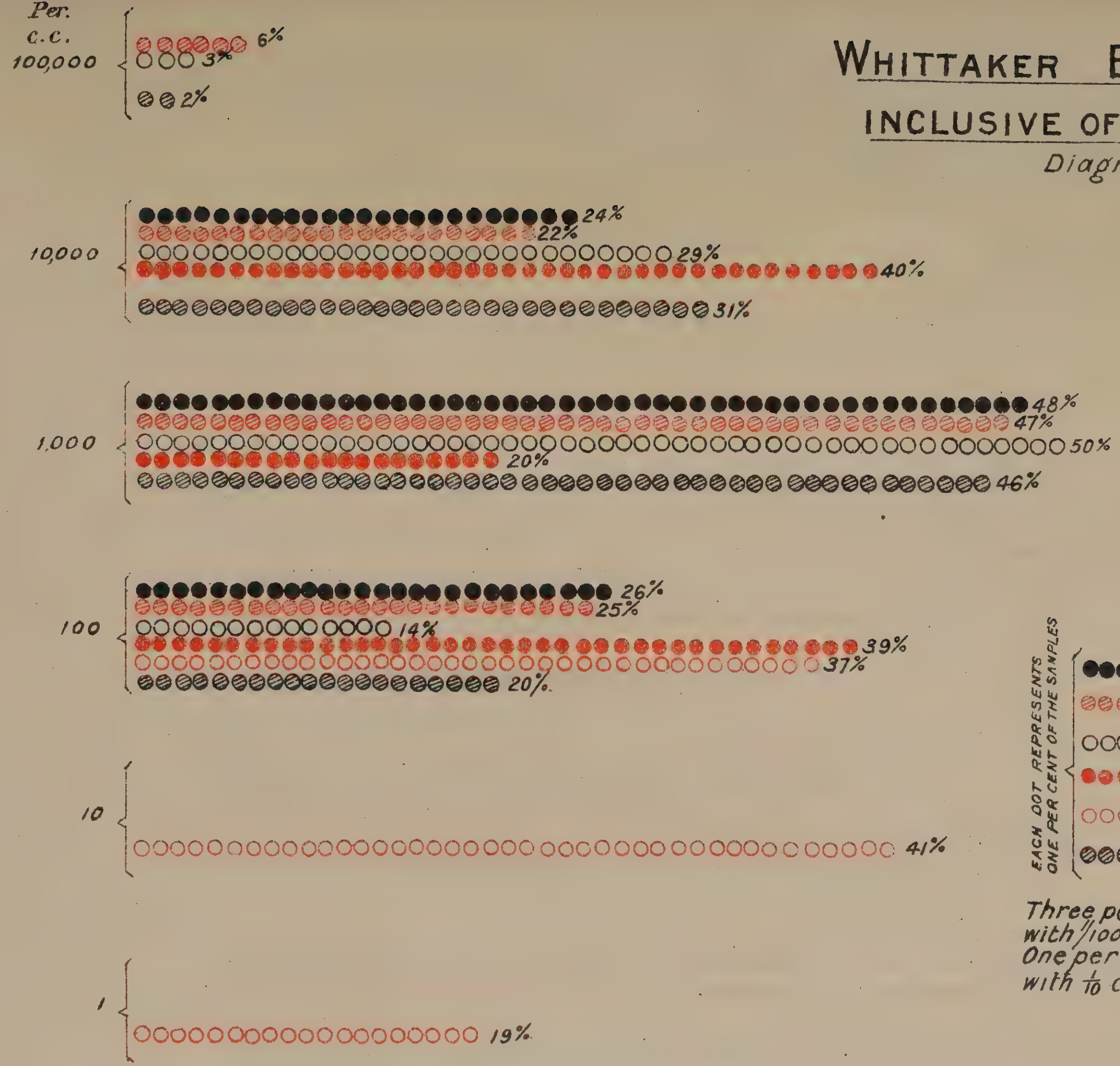
Before filtration - - Varied from + 1 to + ·1 c.c.
After filtration - - With one exception + 1; − ·1 c.c.

* . = before filtration. + = after filtration. Each sign = one per cent. of the samples.

WHITTAKER BED EFFLUENTS

INCLUSIVE OF ALL THE RESULTS.

Diagram L.IX.



EACH DOT REPRESENTS ONE PER CENT OF THE SAMPLES

Represents bile salt glucose peptone test
" " lactose peptone milk test
" " B. coli test
indol test
" " B. enteritidis sporogenes test
" " neutral red broth test

Three per cent of the samples yielded a negative result with 1/1000 c.c. as regards the B coli test
One per cent of the samples yielded a negative result. with $\frac{1}{10}$ c.c. as regards the B. enteritidis sporogenes test.

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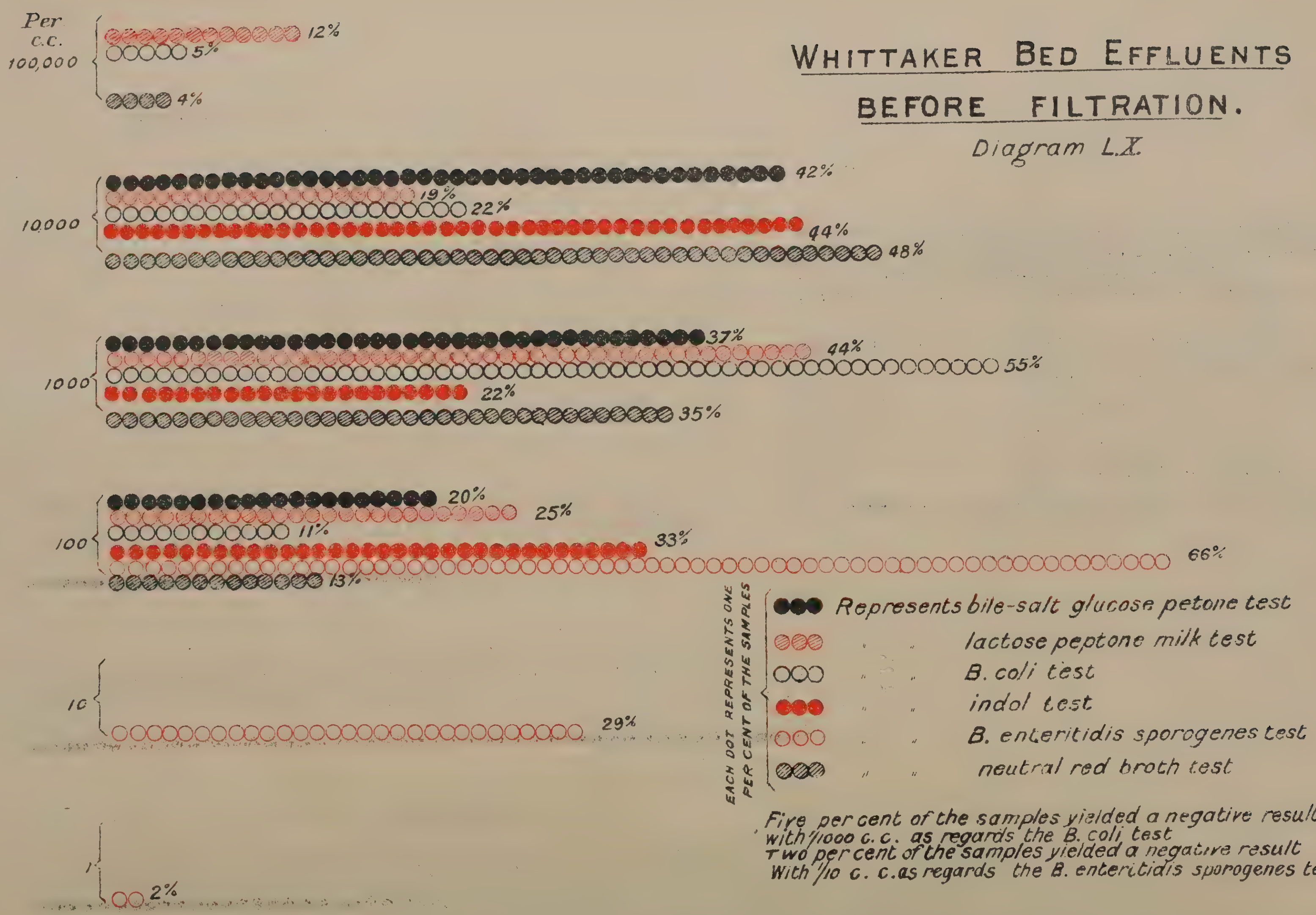
WHITTAKER BED EFFLUENTS
BEFORE FILTRATION.

Diagram L.X.



Five per cent of the samples yielded a negative result with 1/1000 c.c. as regards the B. coli test
Two per cent of the samples yielded a negative result With 1/10 c. c. as regards the B. enteritidis sporogenes test.

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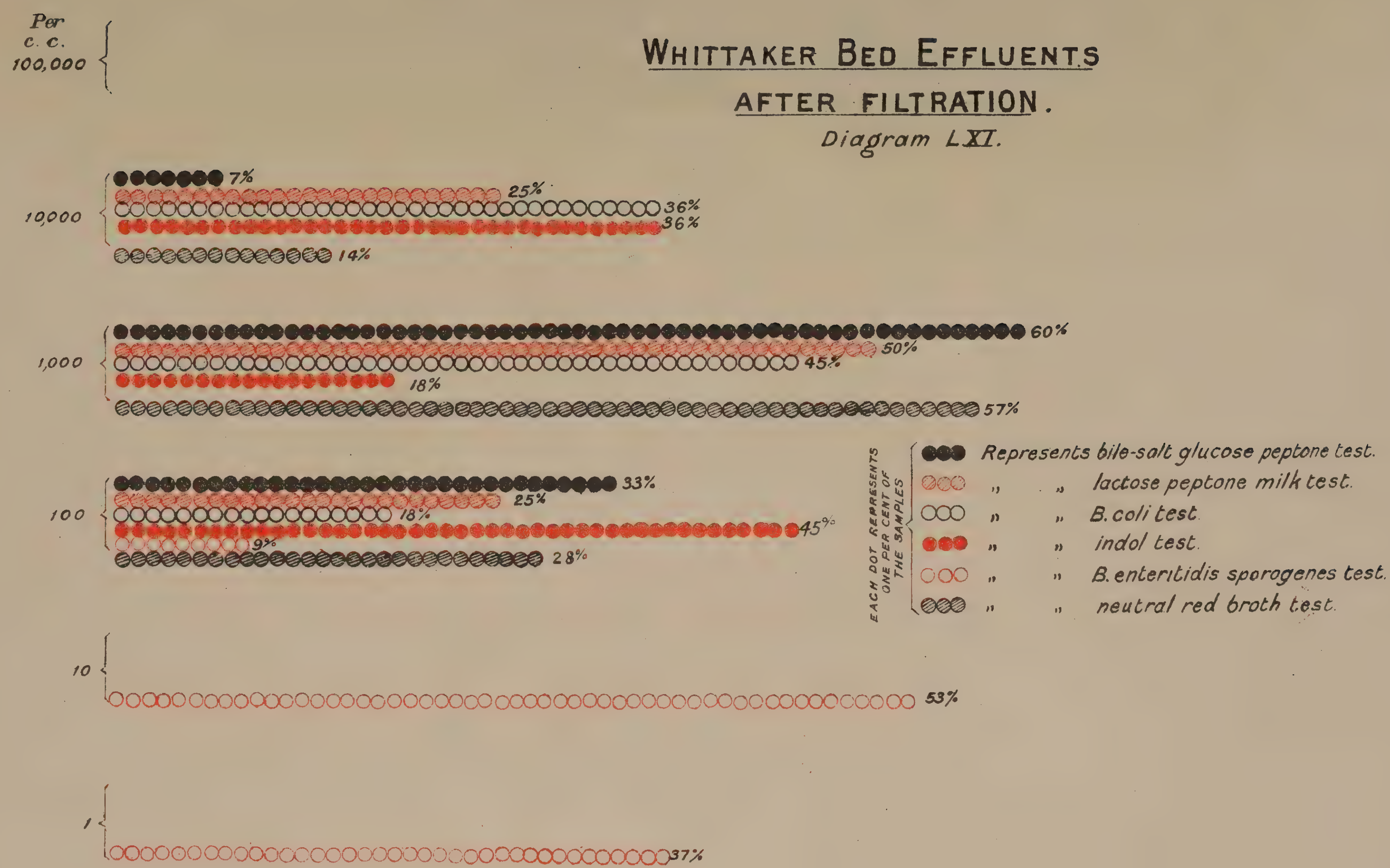
Whittaker Bed Effluents After Filtration.

Diagram LXI.



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Whittaker Bed Effluents.

Neutral Red Broth Test.

	100.	1,000	10,000	100,000
Before filtration - -	3 s. (13 per cent.)	8 s. (35 per cent.)	11 s. (48 per cent.)	1 s. (4 per cent.)
After filtration - -	2 s. (28 per cent.)	4 s. (57 per cent.)	1 s. (14 per cent.)	—

These results may be shown in a diagram as follows :—

Neutral red broth test.

*100,000 { . . . . 4 per cent.

10,000 { . . . . 48 per cent.
+ + + + + + + + + + + + + + 14 per cent.

1,000 { . . . . 35 per cent.
+++ 57 per cent.

100 { . . . . 13 per cent.
+ 28 per cent.

Total Number of Bacteria per c.c. (Agar at 37° C.).

Before filtration - - - - - - - - -	101,000
After filtration - - - - - - - - -	38,272

In conclusion, it is desirable to give three diagrams showing the general results :—

(*a*) Inclusive of all the samples. (Diagram L.IX.)

(*b*) Exclusive of the filtered effluents. (Diagram L.X.)

(*c*) Exclusive of the effluents before filtration. (Diagram L.XI.)

*. = before filtration. + = after filtration. Each sign = one per cent. of the samples.

GENERAL REMARKS

A comparison of Diagram L.I. with L.II. will make it clear that the septic tank liquors were purer (bacteriologically) than the raw or screened sewage.

A comparison of Diagrams L.I and L.II with Diagrams L.III, L.IV, L.V, L.VI, L.VII, L.VIII, L.IX, L.X, and L.XI. show that considered bacteriologically the effluents from the various processes were purer than the tank liquors, and much purer than the raw sewage.

On the whole, the Ducat and Whittaker bed effluents were purer (bacteriologically) than the Cameron, Manchester (No. 2 secondary large bed), and New Leeds filter effluents. But the Ducat and Whittaker bed effluents yielded less satisfactory results with the B. enteritidis sporogenes test than with other tests.

It is to be noted that settlement and rapid filtration through fine material greatly improved the quality of the Whittaker and New Leeds effluents (compare Diagrams L. IV and L.V and Diagrams L.X and L.XI). The beneficial effect of this extra process of treatment seemed to be specially well marked as regards removal of the spores of B. enteritidis sporogenes.

From the point of view of percentage purification, the effluents were, generally speaking, very good, but they could not, I think, be regarded as satisfactory, if considered in relation to their fitness for discharge into drinking-water streams.

ADDENDUM A

Analysis of the Biological Attributes of the B. Coli or coli-like Microbes isolated from the Various Samples of Sewage, Tank Liquor, and Effluent at Leeds.

Inasmuch as Leeds sewage is not purely domestic in character, but contains a considerable proportion of trade refuse, it is especially important to note very briefly the biological characters of the B. coli or coli-like microbes isolated from the various samples.

Total number of B. coli or gas-forming coli-like microbes, 158.

Of these, 105 (about 66 per cent.) produced indol and clotted milk;

23 (about 14 per cent.) produced neither indol in broth culture nor clot in milk culture;

20 (about 12 per cent.) clotted milk, but did not produce indol;

10 (about 6 per cent.) produced indol, but did not clot milk.

The percentage number of coli-like microbes producing both indol in broth culture and clot in milk culture is low in comparison with the number of B. coli, which, found in purely domestic sewage and in normal human fæces, yield a positive result with both these tests. It might be contended, with some show of reason, that a given number of coli-like microbes in a Leeds effluent has not quite the same significance as a similar number occurring in the effluent derived from a purely domestic sewage. Further, that as regards each town the average number of coli-like microbes per unit of sewage or effluent should be not only determined, but also the percentage number of *typical* B. coli, and the results interpreted accordingly. But how best to correlate total abundance of coli-like microbes with the percentage number found to be typical B. coli is another matter. Reverting to the particular case of Leeds, it needs to be remembered that it is not a question of a relative scarcity of typical B. coli, but only that the proportion of typical to atypical B. coli was not found to be quite the same as occurs in purely domestic sewage or in normal human fæces.

Perhaps this matter will be best understood by an illustration:—

Sewage contains about 100,000 B. coli or coli-like microbes per c.c. Hence, if a surface gelatine or agar plate be made with $\frac{1}{1000}$ c.c. of sewage, about 100 colonies of B. coli or coli-like microbes will develop on the plate. Now, if all these 100 colonies were subjected to further subcultural tests, a majority would be found to be typical B. coli, and a minority atypical coli-like microbes. But if the sewage were a purely domestic sewage, more would be found to be typical and fewer atypical than if the sewage contained much trade refuse (*e.g.*, Leeds and Manchester sewage).

It is worth noting that the results afford *no* indication that artificial processes of sewage disposal reduce the *proportion* of typical to non-typical B. coli, although they certainly reduce the total number of B. coli of all sorts. Thus, the *percentage* number of typical B. coli, on the basis of the tests employed, in the crude sewage, septic tank liquor, New Leeds filter effluents, Manchester Bed effluents, Ducat filter effluents, Cameron Bed effluents, and Whittaker filter effluents was 62, 61, 67, 62, 81, 58, and 71 per cent. respectively.

ADDEN

RESULTS OF THE BACTERIOLOGICAL EXAMINATION

1						2						3						4			
Description of the Sample.						B.S. = Bile Salt Glucose Peptone Test (+ = acid and gas). L.P.M. = Lactose Peptone Milk Test (+ = acid gas and clot).						Number of B. Coli (or closely allied forms) in 1 c.c. (Primary broth cultures (48 hours 37° C.) and subsequent surface gelatine plate method.)						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection.				Other Details.													Gas.	Indol.	(a) Acidity. (b) Clot. (Litmus milk cultures, 5 days at 37° C.)	
	Hour.	Day.	Month.	Year.		1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	(Gelatine "shake" cultures, 24 hrs. at 20° C.)	(Both cultures, 5 days at 37° C.)		
						1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.			(a)	(b)
1 ..	2.30 p.m.	2	4	1902	Leeds Precipitation Effluent ..						B.S. + L.P.M.										
2 ..	1.20 p.m.	18	·	1904	Leeds Precipitation Effluent ..						B.S. + L.P.M.						+	+	—	+	+
3 ..	2 p.m.	19	7	1904	Leeds Precipitation Effluent ..						B.S. + L.P.M.						+	+	+	+	+
4 ..	[illegible] p.m	20	7	1904	Leeds Precipitation Effluent ..						B.S. + L.P.M.						+	+	—	+	—
5 ..	2.50 p.m.	21	7	1904	Leeds Precipitation Effluent ..						B.S. + L.P.M.						+	+	+	+	+

DUM B.

OF THE LEEDS PRECIPITATION EFFLUENT.

5					6						7						8
Indol Test. Indol in broth cultures direct (5 days at 37° C).					B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						Neutral-red Broth Test. Greenish-yellow fluorescence, 48 hours at 37° C.						REMARKS.
10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	
·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	
								+	—						+	—	Sample 1 gave "gas" in gelatine "shake" culture with ·001 c.c. in 24 hours at 20° C.
				+				+	—							+	
				+				+	—							+	
				+				+	—							+	
				+				+	—							+	

DESCRIPTION OF MICRO-PHOTOGRAPHS.

PLATES I AND II.

B. enteritides sporogenes test, showing Klein's "B. enteritidis sporogenes changes" in anaerobic spore milk cultures.

(+ indicates a positive ; – indicates a negative result with the tests.)

PLATE I.

Figure 1.—Sample No. 7—19th March, 1902. Leeds crude sewage: + $\frac{1}{10}$, $\frac{1}{100}$ and $\frac{1}{1000}$ c.c. ; — $\frac{1}{10000}$ c.c.

Figure 2.—Sample No. 31—19th March, 1902. Screened sewage for New Leeds filter: + $\frac{1}{10}$, $\frac{1}{100}$, and $\frac{1}{1000}$ c.c. ; — $\frac{1}{10000}$ c.c.

Figure 3.—Sample No. 37—19th March, 1902. Screened sewage for Old Leeds filter: + $\frac{1}{10}$, $\frac{1}{100}$ and $\frac{1}{1000}$ c.c. ; — $\frac{1}{10000}$ c.c.

Figure 4.—Sample No. 8—19th March, 1902. Septic tank liquor for Whittaker Bed: + $\frac{1}{10}$ c.c. ; — $\frac{1}{100}$; $\frac{1}{1000}$, and $\frac{1}{10000}$ c.c.

PLATE II.

Figure 5.—Sample No. 7—19th March, 1902. Effluent from New Leeds filter: + 1, $\frac{1}{10}$ and $\frac{1}{100}$ c.c. ; —$\frac{1}{1000}$ c.c.

Figure 6.—Sample No. 8—19th March, 1902. Effluent from No. 2. Whittaker Bed: + 1, $\frac{1}{10}$, and $\frac{1}{100}$ c.c. ; — $\frac{1}{1000}$ c.c.

Figure 7.—Sample No. 5—19th March, 1902. Effluent from Old Leeds filter: + 1, $\frac{1}{10}$, and $\frac{1}{100}$ c.c. ; — $\frac{1}{1000}$ c.c.

PLATES III, IV, AND V.

"Gas" test ("gas" in gelatine "shake" cultures, 24 *hours at* 20° *C.*).

PLATE III.

Figure 8.—Sample No. 7—19th March, 1902. Leeds crude sewage: + $\frac{1}{10}$ and $\frac{1}{100}$ c.c. ; — $\frac{1}{1000}$ and $\frac{1}{10000}$ c.c.

Figure 9.—Sample No. 31—19th March, 1902. Screened sewage for New Leeds filter: + $\frac{1}{10}$ and $\frac{1}{100}$ c.c. ; — $\frac{1}{1000}$ and $\frac{1}{10000}$ c.c.

PLATE IV.

Figure 10.—Sample No. 37—19th March, 1902. Screened sewage for Old Leeds filter: + $\frac{1}{10}$ and $\frac{1}{100}$ c.c. ; — $\frac{1}{1000}$ and $\frac{1}{10000}$ c.c.

Figure XI.—Sample No. 8--19th March, 1902. Septic tank liquor for Whittaker Bed: + $\frac{1}{10}$ c.c. ; —$\frac{1}{100}$, $\frac{1}{1000}$ and $\frac{1}{10000}$ c.c.

PLATE V.

Figure 12.—Sample No. 7—19th March, 1902 Effluent from New Leeds filter: + 1 and $\frac{1}{10}$ c.c. ; —$\frac{1}{100}$ and $\frac{1}{1000}$ c.c.

Figure 13.—Sample No. 8—19th March, 1902. Effluent from No. 2, Whittaker Bed: + 1 c.c. ; — $\frac{1}{10}$, $\frac{1}{100}$ and $\frac{1}{1000}$ c.c.

Figure 14.—Sample No. 5—19th March, 1902. Effluent from Old Leeds filter: + 1 and $\frac{1}{10}$ c.c. ; — $\frac{1}{100}$ and $\frac{1}{1000}$ c.c.

PLATE I.

FIGURE 1.

FIGURE 2.

FIGURE 3.

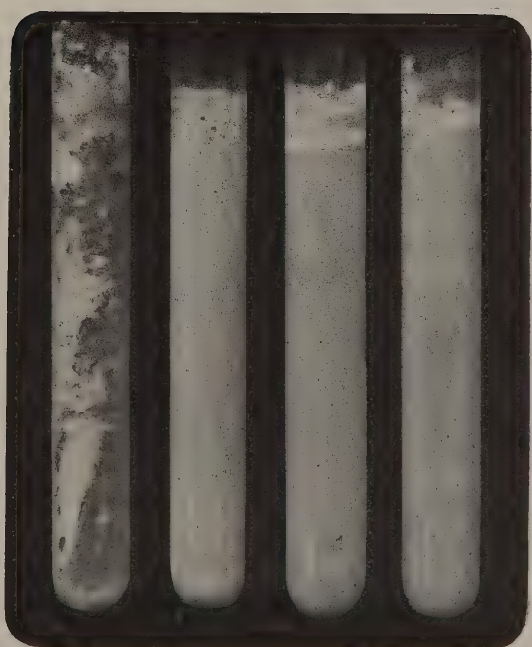

FIGURE 4.

PLATE II.

Figure 5.

Figure 6.

Figure 7.

PLATE III.

Figure 8.

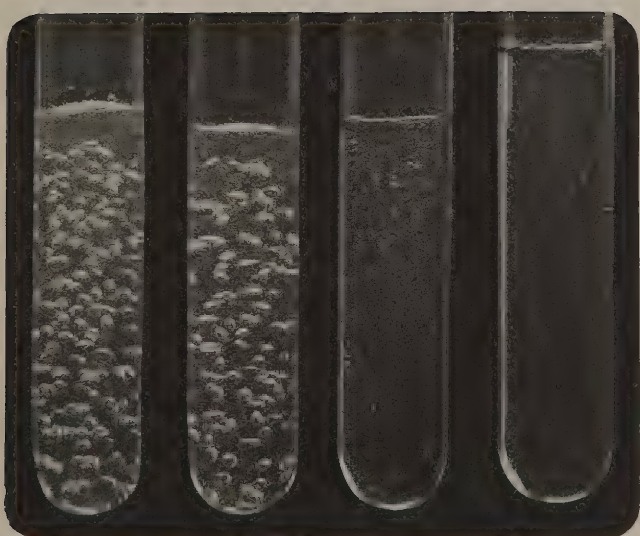

Figure 9.

PLATE IV.

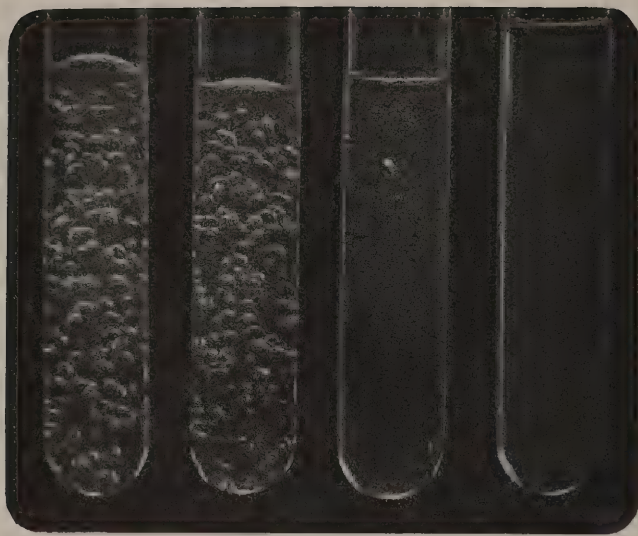

FIGURE 10.

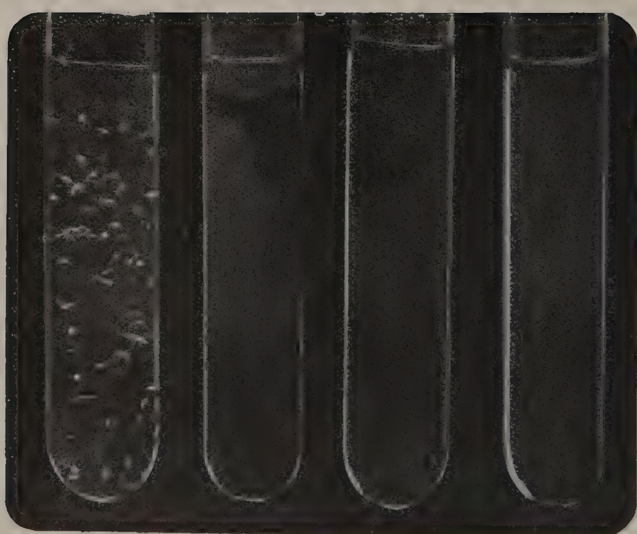

FIGURE 11.

PLATE V.

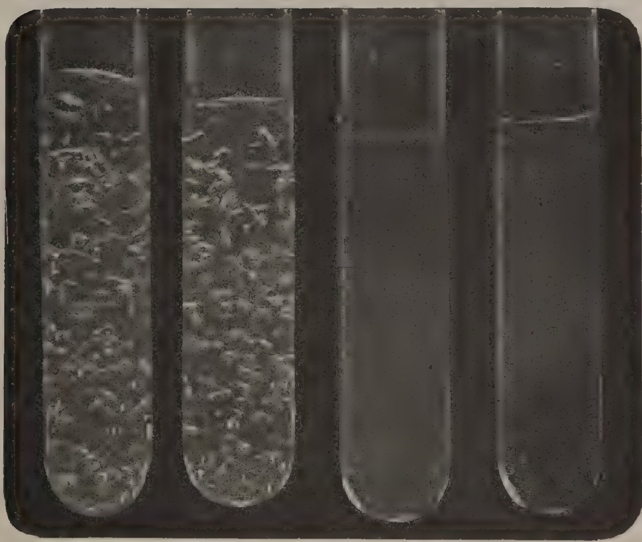

FIGURE 12.

FIGURE 13.

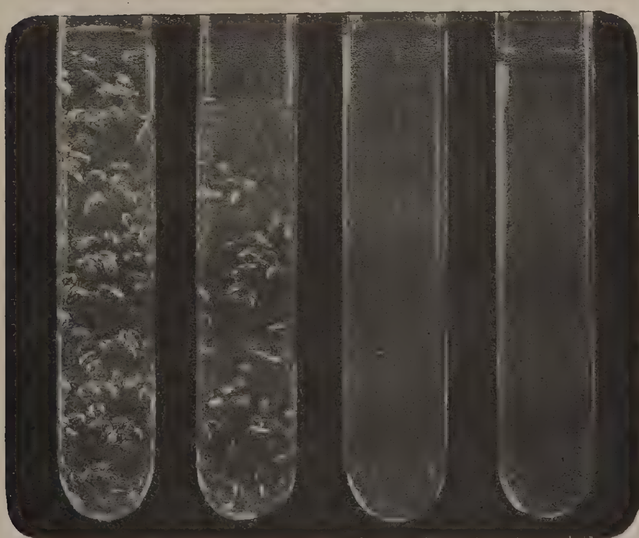

FIGURE 14.

MANCHESTER.

RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF

RAW AND SETTLED SEWAGE.
SEPTIC TANK LIQUOR.
CHEMICALLY PRECIPITATED SEWAGE.
EFFLUENTS FROM MATURE HALF-ACRE PRIMARY CONTACT BEDS.
EFFLUENTS FROM NEW (NOT MATURE) HALF-ACRE PRIMARY CONTACT BEDS.
EFFLUENTS FROM EXPERIMENTAL PRIMARY BEDS A, B, & C.
EFFLUENTS FROM EXPERIMENTAL SECONDARY BED D.
EFFLUENTS FROM THE STODDART FILTER.
EFFLUENTS FROM ROSCOE COKE AND CINDER FILTERS, DUNBAR FILTER, &c.
EFFLUENTS FROM STORM BEDS.

CONTENTS.

A. C. HOUSTON.

May, 1905.

RESULTS OF THE BACTERIOLOGICAL

1						2		3						4			
DESCRIPTION OF THE SAMPLE.						Total Number of Bacteria in 1 c.c.		Number of B. Coli (or closely allied forms) in 1 c.c.						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection. Hour.	Day.	Month.	Year.	Other Details.	Gelatine at 20° C.	Agar at 37° C.	1 — 1 c.c.	10 — ·1 c.c.	100 — ·01 c.c.	1,000 — ·001 c.c.	10,000 — ·0001 c.c.	100,000 — ·00001 c.c.	Gas. (Gelatine "shake" cultures, 24 hrs. at 20° C.)	Indol (Broth cultures, 5 days at 37° C.)	(a) Acidity. (Litmus milk cultures, 5 days at 37° C.)	(b) Clot. (Litmus milk cultures, 5 days at 37° C.)
1	5.15 p.m.	10	3	1902	Manchester Raw Sewage	8,600,000	2,000,000	...	...	...	...	...	+	+	–	+	+
2	3.15 p.m.	11	3	„	do. do.	12,000,000	1,700,000	...	...	...	...	...	+	+	–	–	–
3	9.10 a.m.	14	3	„	do. do.	1,100,000	32,000	...	...	...	...	+	...	+	–	+	+
4	10.35 a.m.	19	3	„	do. do.	1,000,000	160,000	..	...	...	+	...	...	+	+	+	+
5	4.30-5 p.m.	25	4	„	do. do.	500,000	40,000	...	...	...	...	+	...	+	–	–	–
6	9.45-10.15 a.m.	29	4	„	do. do.	540,000	87,000	...	...	...	...	+	...	+	–	+	–
7	9.30-10 a.m.	1	5	„	do. do.	200,000	43,000	...	...	...	+	...	...	+	+	+	+
8	4.30-5 p.m.	2	5	„	do. do.	7,000,000	1,100,000	...	...	...	...	...	+	+	+	+	+
9	4 p.m.	6	5	„	do. do.	3,300,000	410,000	...	...	...	...	...	+	+	–	+	+
10	4 p.m.	9	5	„	do. do.	1,500,000	250,000	...	..	...	...	...	+	+	+	+	+
11	4 p.m.	13	5	„	do. do.	4,800,000	1,300,000	...	...	...	...	...	+	+	–	+	+
12	3.15-3.30 p.m.	19	5	„	do. do.	29,000,000	2,700,000	...	...	...	...	...	+	+	–	+	+
13	4.45-5 p.m.	22	5	„	do. do.	9,300,000	860,000	...	...	...	...	...	+	+	–	+	+
14	3-3.15 p.m.	23	5	„	do. do	14,000,000	2,900,000	...	...	...	...	...	+	+	–	+	–
15	3.30 p.m.	30	5	„	do. do.	9,400,000	2,700,000	...	...	...	–	...	...	...	...	...	...
16	3.30 p.m.	4	6	„	do. do.	17,000,000	2,100,000	...	...	...	+	...	...	+	+	+	+
17	4.30 p.m.	5	6	„	do. do.	18,000,000	6,500,000	...	...	...	...	...	+	+	–	+	+
18	3.15 p.m.	9	6	„	do. do.	18,000,000	2,400,000	...	...	...	...	...	+	+	–	+	+
19	12.30 p.m.	11	6	„	do. do.	4,600,000	1,700,000	...	...	...	...	+	...	+	–	+	+
20	4.45 p.m.	12	6	„	do. do.	7,100,000	...	...	...	...	...	...	+	+	+	+	–
21	4 p.m.	16	6	„	do. do.	19,000,000	5,900,000	...	...	...	...	...	+	+	+	+	+
22	4.15-4.30 p.m.	17	6	„	do. do.	10,000,000	8,500,000	...	...	...	...	...	+	+	–	+	+
23	4.50 p.m.	23	7	„	do. do.	4,600,000	1,100,000	...	...	...	...	...	+	+	–	+	+
24	—	12	8	„	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
25	—	20	8	„	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
26	--	27	8	„	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
27	—	2	9	„	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
28	—	16	9	„	do. do.	...	...	..	...	...	...	...	...	...	...	...	...
29	4.30 p.m.	19	9	„	do. do.	32,000,000	13,000,000	...	...	...	...	...	+	+	+	+	+
30	12.0 noon.	23	9	„	do. do.	10,000,000	1,800,000	...	...	...	...	+	...	+	–	+	–
31	5.0 p.m.	26	9	„	do. do.	17,000,000	7,000,000	...	...	...	...	...	+	+	+	+	+
32	5.30 p.m.	30	9	„	do. do.	19,000,000	9,000,000	...	...	...	. .	...	+	+	–	+	+
33	4.30 p.m.	3	10	„	do. do.	8,300,000	1,000,000	...	...	...	...	...	+	+	–	+	–
34	5.0 p.m.	7	10	„	do. do.	18,000,000	3,100,000	...	...	...	...	..	+	+	–	+	–
35	5.0 p.m.	10	10	„	do. do.	18,000,000	2,000,000	...	...	...	...	...	+	+	–	+	–
36	...	14	10	„	do. do.	...	330,000	...	...	...	...	+	...	+	–	+	–
37	3.10 p.m.	17	10	„	do. do.	13,000,000	2,900,000	...	...	...	...	...	+	+	–	Alk	–
38	5.0 p.m.	21	10	„	do. do.	11,000,000	1,700,000	...	..	...	...	...	+	+	–	+	+
39	3.0 p.m.	23	10	„	do. do.	4,600,000	250,000	...	..	...	...	...	+	+	–	+	+
40	4.15-4.30 p.m.	2	11	„	do. do.	9,000,000	3,000,000	...	...	...	...	...	+	+	–	+	—

XAMINATION OF MANCHESTER SEWAGE.

	5					6						7						8
	Indol Test. Indol in broth cultures direct (5 days at 37° C.)					B. Enteritidis Sporogenes Test. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						Other Tests. B. = Acid and gas, bile salt glucose peptone test. L. = Acid and gas lactose pepton test. N.R. = Greenish-yellow fluorescence, neutral red broth test.						REMARKS.
	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	
c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	
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.	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	L +	

Gas Test.

Samples 25, 26, 27, 28 yielded results respectively as follows:

24 hours.

(25) + ·001 c.c., − ·0001 c.c.
(26) + ·0001 c.c., − ·00001 c.c.
(27) + ·001 c.c., − ·0001 c.c.
(28) + ·01 c.c., − ·001 c.c.

48 hours.

(25) + ·00001 c.c.
(26) + ·00001 c.c.
(27) + ·0001 c.c.
(28) + ·0001 c.c., − ·00001 c.c.

Litmus Milk Modified Test.

Samples 24, 25, 26, 27, 28 yielded results as follows:—

(24) + ·0001 c.c., − ·00001 c.c.
(25) + ·00001 c.c., (26) + ·00001 c.c.
(27) + ·00001 c.c., (28) + ·00001 c.c.

Sample 29 gave a positive result with ·00001 c.c. with the Litmus milk modified test.

Sample 30 gave results as regards Gas test:—

(*a*) 24 hours,
+ ·01 c.c., − ·001 c.c.

(*b*) 48 hours,
+ ·0001 c.c., − ·00001 c.c.

RESULTS OF THE BACTERIOLOGICAL

1						2		3						4			
DESCRIPTION OF THE SAMPLE.						Total Number of Bacteria in 1 c.c.		Number of B. Coli (or closely allied forms) in 1 c.c.						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection. Hour.	Day.	Month.	Year.	Other Details.	Gelatine at 20° C.	Agar at 37° C.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	Gas. (Gelatine "shake" cultures, 24 hours at 20° C.)	Indol. (Broth cultures, 5 days at 37° C.)	(a) Acidity. (Litmus milk cultures, 5 days at 37° C.)	(b) Clot.
41	5.0 p.m.	14	11	1902	Manchester Raw Sewage	12,000,000	2,400,000	..	...	...	...	...	+	+	+	+	+
42	4.45 p.m.	19	11	,,	do. do.	19,000,000	3,800,000	...	...	...	...	...	+	+	+	+	+
43	4.30—5.0 p.m.	21	11	,,	do. do.	1,300,000	3,400,000	...	...	...	...	...	+	+	–	+	+
44	4.0 p.m.	24	11	,,	do. do.	...	440,000	...	...	...	...	+	...	+	–	+	–
45	11.0 a.m.	26	11	,,	do. do.	...	1,700,000	...	...	...	...	+	...	+	–	+	–
46	12.0 noon.	28	11	,,	do. do.	...	550,000	...	...	...	...	+	...	+	+	+	+
47	...	2	12	,,	do. do.	1,500,000	300,000	...	...	...	+	...	...	+	+	+	+
48	3.45 p.m.	4	12	,,	do. do.	4,200,000	480,000	...	...	...	...	...	+	+	–	+	+
49	2.30—3.0 p.m.	8	12	,,	do. do.	...	3,000,000	...	...	...	...	...	+	+	No	reco	rds
50	4.30 p.m.	12	12	,,	do. do.	2,100,000	600,000	...	...	...	+	...	...	+	–	+	–
51	3.0 p.m.	29	1	1903	do. do.	11,000,000	1,200,000	...	...	...	+	...	...	+	+	–	–
52	4.45 p.m.	30	1	,,	do. do.	10,000,000	790,000	...	...	...	...	...	+	+	No	reco	rds
53	3.40 p.m.	5	2	,,	do. do.	...	3,300,000	...	...	...	...	...	+	+	–	+	–
54	4.35 p.m.	19	2	,,	do. do.	...	2,700,000	...	...	...	...	...	+	+	No	reco	rds
55	4.45 p.m.	3	9	1904	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
56	...	8	9	,,	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
57	3.30—4.15 p.m.	14	9	,,	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
58	2.30—3.30 p.m.	20	9	,,	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
59	...	29	9	,,	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
60	...	5	10	,,	do. do.	...	...	...	...	...	..	...	...	...	..	...	...
61	...	16	10	,,	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
62	...	19	10	,,	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
63	...	26	10	,,	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
64	2.15—4 p.m.	15	11	,,	do. do.	...	...	...	...	...	...	...	...	..	...	...	...
65	...	23	11	,,	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
66	3.30—4 p.m.	29	11	,,	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
67	4.30 p.m.	7	12	,,	do. do.	...	...	...	...	...	...	...	...	...	...	...	..
68	3—3.30 p.m.	13	12	,,	do. do.	...	...	...	..	...	...	...	...	...	...	...	...
1	4.30 p.m.	3	9	,,	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
2	...	8	9	,,	do. do.	...	...	...	..	...	...	...	...	...	...	...	..
3	...	14	9	,,	do. do.	...	...	...	...	...	...	...	...	...	...	...	..
4	...	20	9	,,	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
5	...	27	9	,,	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
6	...	23	11	,,	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
					Averages per c.c. (inclusive of all the results).	10,036,666	2,379,625	33 samples at 100,000, 9 samples at 10,000, 6 samples at 1,000 per c.c. 1 sample less than 1,000 per. c.c.						12 out of 45 produced both indol and clot. 15 out of 45 produced neither indol nor clot. 16 out of 45 produced clot but no indol. 2 out of 45 produced indol but no clot.			

XAMINATION OF MANCHESTER SEWAGE—*continued.*

5					6						7						8
INDOL TEST. Indol in broth cultures direct (5 days at 37° C.)					B. ENTERITIDIS SPOROGENES TEST. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures. Cultures heated to 80° C. for 10 minutes.						OTHER TESTS. B. = Acid and gas, bile salt glucose peptone test. L. = Acid and gas, lactose peptone test. N.R. = Greenish-yellow fluorescence neutral red broth test.						REMARKS.
10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	·00001	1	10	100	1,000	10,000	100,000	
·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	100,000 c.c.	1 c.c.	.1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	
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samples at 100,000 }
samples at 10,000 } per c.c.
samples at 1,000 }

10 samples + ·001c.c., − ·0001c.c.
16 samples + ·01c.c., − ·001c.c.

Bile Salt Glucose Peptone Test.
11 samples at 100,000 }
9 samples at 10,000 } per c.c.
4 samples at 1,000 }

Lactose Peptone Test.
10 samples at 100,000 }
1 sample at 10,000 } per c.c.

Neutral Red Broth Test.
23 samples at 100,000 }
3 samples at 10,000 } per c.c.

Gas Test.

The samples tested varied between :—

(*a*) Examined after 24 hours,

+ ·01 c.c., − ·001 c.c.
+ ·0001 c.c., − ·00001 c.c.

(*b*) Examined after 48 hours,

+ 0001 c.c., − ·00001 c..c,
+ ·00001 c.c.

Litmus Milk Modified Test.

5 samples + ·00001 c.c.
1 sample + 0001 c.c., − ·00001 c.c.

RESULTS OF THE BACTERIOLOGICAL EXAMINATION

1						2		3						4			
DESCRIPTION OF THE SAMPLE.						Total Number of Bacteria in 1 c.c.		Number of B. Coli (or closely allied forms) in 1 c.c.						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection.				Other Details.	Gelatine at 20° C.	Agar at at 37° C.	1	10	100	1,000	10,000	100,000	Gas. (Gelatine "shake" cultures, 24 hrs. at 20° C.)	Indol. (Broth cultures, 5 days at 37° C.)	(a) Acidity. (b) Clot. (Litmus milk cultures, 5 days at 37° C.	
	Hour.	Day.	Month	Year.				1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.			(a)	(b)
1	5.15 p.m.	10	3	190	Open Septic Tank Liquor. No. 1.	2,300,000	210,000	...	...	...	...	+	...	+	–	+	–
2	9.10 a.m.	14	3	,,	do. do.	230,000	28,000	...	...	...	+	...	...	+	+	–	–
3	11. 0 a.m.	18	3	,,	do. do.	83,000	2,000	...	+	..	...	...	...	+	–	+	–
4	10.45 a.m.	19	3	,,	do. do.	410,000	74,000	...	...	+	...	...	...	+	–	+	+
5	4.30–5.0 p.m.	25	4	,,	do. do.	600,000	59,000	...	...	...	+	...	...	+	–	+	+
6	9.45–10.15 a.m.	29	4	,,	do. do.	680,000	100,000	...	...	...	...	+	...	+	–	+	+
7	9.30–10.0 a.m.	1	5	,,	do. do.	2,300,000	230,000	...	...	...	...	+	...	+	+	+	+
8	4.30–5.0 p.m.	2	5	,,	do. do.	2,600,000	450,000	...	...	...	...	...	+	+	–	–	–
9	4. 0 p.m.	6	5	,,	do. do.	520,000	21,000	...	...	...	+	...	...	+	+	+	+
10	4. 0 p.m.	9	5	,,	do. do.	880,000	28,000	...	...	...	...	+	...	+	–	+	–
11	4. 0 p.m.	13	5	,,	do. do.	2,400,000	55,000	...	...	...	+	...	...	+	+	+	+
12	3.15-3.30 p.m.	19	5	,,	do. do.	3,300,000	720,000	...	...	...	...	+	...	+	–	+	+
13	4.45-5.0 p.m.	22	5	,,	do. do.	18,000,000	4,300,000	...	...	...	...	...	+	+	+	+	+
14	3.0-3.15 p.m.	23	5	,,	do. do.	12,000,000	2,300,000	...	...	...	...	...	+	+	+	+	+
15	8.30–8.45 a.m.	25	5	,,	do. do.	12,000,000	1,700,000	...	...	...	...	...	+	+	+	+	+
16	3.30 p.m.	30	5	,,	do. do.	5,100,000	860,000	...	...	...	...	...	+	+	–	+	+
17	3.30 p.m.	4	6	,,	do. do.	15,000,000	1,200,000	...	...	...	...	...	+	+	+	+	+
18	3.15 p.m.	9	6	,,	do. do.	3,700,000	760,000	...	...	...	...	...	+	+	–	+	–
19	12.20 p.m.	11	6	,,	do. do.	6,200,000	750,000	...	...	...	...	...	+	+	–	+	–
20	4.45 p.m.	12	6	,,	do. do.	11,000,000	1,800,000	...	...	...	...	...	+	+	+	+	+
21	4. 0 p.m.	16	6	,,	do. do.	9,700,000	810,000	...	...	...	...	...	+	+	–	+	+
22	4.15–4.30 p.m.	17	6	,,	do. do.	15,000,000	1,900,000	...	...	...	...	...	+	+	–	–	–
23	5. 0 p.m.	21	7	,,	do. do.	2,300,000	720,000	...	...	...	...	...	+	+	+	+	+
24	4.50 p.m.	23	7	,,	do. do.	7,600.000	2,300,000	...	...	...	...	...	+	+	–	–	–
25 (79)	4.40 p.m.	5	8	,,	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
26 (80)	—	12	8	,,	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
27 (81)	—	20	8	,,	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
28 (82)	—	2	9	,,	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
29 (83)	—	16	9	,,	do. do.	...	...	..	...	..	...	..	...	...	...	...	...
30 (84)	4.30 p m.	19	9	,,	do. do.	3,200,000	1,300,000	...	...	...	–	...	...	...	...	...	...
31	12 noon –1 p.m.	23	9	,,	do. do.	10,000,000	2,800,000	...	...	...	...	...	+	+	–	+	+
32	5. 0 p.m.	26	9	,,	do. do.	4,000,000	2,000,000	...	...	...	...	...	+	+	–	+	–
33	5.30 p.m.	30	9	,,	do. do.	4,200,000	1,300,000	...	...	...	...	...	+	+	–	+	+
34	4.30 p.m.	3	10	,,	do. do.	5,000,000	670,000	...	...	...	...	...	+	+	+	+	+
35	5. 0 p.m.	7	10	,,	do. do.	2,300,000	100,000	...	...	...	...	+	...	+	–	+	–
36	5. 0 p.m.	10	10	,,	do. do.	7,400,000	770,000	...	...	...	...	+	...	+	–	+	+
37	...	14	10	,,	do. do.	...	1,000,000	..	...	...	...	+	...	+	–	–	–
38	3.10 p.m.	17	10	,,	do. do.	3,200,000	290,000	...	...	...	...	...	+	+	–	+	+
39	5. 0 p.m.	21	10	,,	do. do.	2,100,000	270,000	...	...	...	...	...	+	+	–	+	+
40	2.40 p.m.	23	10	,,	do. do.	2,100,000	60,000	...	...	...	–	...	...	...	...	...	...
41	4.15–4.30 p.m.	12	11	,,	do. do.	8,400,000	260,000	...	...	...	...	...	+	+	–	+	–
42	4.45 p.m.	19	11	,,	do. do.	5,000,000	1,300,000	...	...	...	...	...	+	+	–	+	–

F MANCHESTER SEPTIC TANK LIQUOR.

5						6						7					
INDOL TEST. Indol in broth cultures direct (5 days at 37° C.)						B. ENTERITIDIS SPOROGENES TEST. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						OTHER TESTS. B. = Acid and gas, bile salt glucose peptone test. L. = Acid and gas lactose peptone test. N.R. = Greenish-yellow fluorescence, neutral red broth test.					
1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000
1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.
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REMARKS.

Gas Test.

Samples 79, 80, 82, 83 gave results as follows:—

24 hours.

(79) + ·1 c.c., − ·01 c.c.
(80) + ·001 c.c., − ·0001 c.c.
(82) + ·01 c.c., − ·001 c.c.
(83) + ·01 c.c. − ·001 c.c.

48 hours.

(79) No record
(80) + ·0001 c.c., − ·00001 c.c.
(81) + ·001 c.c., − ·0001 c.c.
(82) + ·001 c.c., − ·0001 c.c.

Litmus Milk Modified Test.

Samples 79, 80, 81, 82, 83, gave results respectively as follows:—

+ ·00001 c.c.
+ ·0001 c.c., − ·00001 c.c.
+ ·00001 c.c.
+ ·0001 c.c., − ·00001 c.c.
+ ·0001 c.c., − ·00001 c.c.

Sample 30 (84) gave a positive result with ·00001 c c. with the Litmus milk, modified test.

RESULTS OF BACTERIOLOGICAL EXAMINATION

1						2		3						4			
DESCRIPTION OF THE SAMPLE.						Total Number of Bacteria in 1 c.c.		Number of B. Coli (or closely allied forms) in 1 c.c.						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection. Hour.	Day.	Month.	Year.	Other Details.	Gelatine at 20° C.	Agar at 37° C.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	Gas. (Gelatine "shake" cultures, 24 hrs at at 20° C).	Indol. (Broth culture, 5 days at 37° C.)	(a) Acidity.	(b) Clot. (Litmus milk cultures, 5 days at 37° C.)
43	4.30–5.0 p.m.	21	11	1902	Open Septic Tank Liquor. No. 1.	12,000,000	2,400,000	...	...	...	...	...	+	+	–	+	+
44	4. 0 p.m.	24	11	,,	do. do.	...	1,300,000	...	...	...	...	+	...	+	–	+	+
45	11. 0 a.m.	26	11	,,	do. do.	...	1,600,000	...	...	...	...	...	+	+	–	+	–
46	...	2	12	,,	do. do.	4,800,000	520,000	...	...	...	...	...	+	+	–	+	+
47	3.45 p.m.	4	,,	,,	do. do.	11,000,000	1,500,000	...	..	...	...	...	+	+	–	+	–
48	2.30–3. 0 p.m.	8	,,	,,	do. do.	6,700,000	270,000	...	...	...	...	...	+	+	–	+	–
49	3.7 p.m.	29	1	1903	do. do.	2,600,000	80,000	...	...	...	+	...	...	+	+	+	–
50	4.35 p.m.	19	2	,,	do. do.	4,100,000	560,000	...	...	...	...	...	+	+	+	+	+
51	3.15–3.30 p.m.	19	5	1902	Open Septic Tank Liquor. No. 2	3,900,000	300,000	...	...	...	...	...	+	+	–	+	+
52	4.45–5. 0	22	,,	,,	do. do.	6,300,000	280,000	...	...	...	...	...	+	+	–	+	–
53	3–3 15 p.m.	23	,,	,,	do. do.	...	210,000	–	...	...	...	...	+	+	–	+	–
54	3.30 p.m.	30	,,	,,	do. do.	9,400,000	1,500,000	...	...	...	...	...	+	+	–	+	+
55	5. 0 p.m.	14	11	,,	do. do.	18,000,000	1,900,000	...	...	...	...	...	+	+	+	+	–
56	4.35 p.m.	30	1	1903	do. do.	11,000,000	490,000	...	...	...	+	...	...	+	–	+	+
57	4,5 p.m.	3	2	,,	do. do.	...	120,000	...	...	...	+	...	...	+	–	+	–
58	3.35 p.m.	5	,,	,,	do. do.	...	130,000	...	...	...	...	+	...	+	–	+	–
59	...	3	9	1904	Septic Tank Effluent	...	...	...	...	...	...	..	..	...	...	...	...
60	...	8	9	,,	Open Septic Tank Effluent.	...	...	...	...	...	...	...	...	...	...	..	...
61	3.30 to 4.15 p.m.	14	9	,,	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
62	2.30 to 3.30 p.m.	20	9	,,	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
63	...	27	9	,,	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
64	...	5	10	,,	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
65	...	10	10	,,	do. do.	...	...	...	...	...	..	...	...	...	...	...	...
66	...	19	10	,,	do. do.	...	..	...	...	...	...	...	...	...	...	...	...
67	...	26	10	,,	do. do.	...	...	...	...	...	...	...	..	...	...	...	...
68	2.15 to 4 p.m.	15	11	,,	do. do.	...	...	...	...	...	...	...	...	...	..	...	...
69	...	23	11	,,	do. do.	...	...	...	...	...	..	...	...	...	...	...	...
70	3.30 to 4 p.m.	29	11	,,	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
71	4.30 p.m.	7	12	,,	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
72	3 to 3.30 p.m.	13	12	,,	do. do.	...	...	...	...	...	...	...	...	..	...	...	...
1	3.15 p.m.	11	3	,,	Closed Septic Tank (Cameron) Liquid.	11,000,000	3,600,000	...	...	...	...	...	+	+	–	+	–
2	9.45 to 10.15 a.m.	29	4	,,	do. do.	2,900,000	240,000	...	...	...	+	...	...	+	–	+	+
3	3 25 p.m.	2	9	,,	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
4	12 noon.	28	11	,,	do. do. (recently restarted).	...	8,300,000	...	...	...	...	+	...	+	–	+	–
					Averages per c.c. (inclusive of all samples).	6,010,265	1 049,946	33 samples at 100,000 11 samples at 10,000 8 samples at 1,000 1 sample at 100 1 sample at 10 } per c.c. 2 samples less than 1,000 per c.c.						11 out of 54 produced both indol and clot. 22 out of 54 produced neither indol nor clot. 18 out of 54 produced clot but no indol. 3 out of 54 produced indol but no clot.			

OF MANCHESTER SEPTIC TANK LIQUOR—*continued.*

5						6						7						8
INDOL TEST. Indol in broth cultures direct (5 days at 37° C.)						B. ENTERITIDIS SPOROGENES TEST. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures. Cultures heated to 80° C. for 10 minutes.						OTHER TESTS. B = Acid and gas, bile salt glucose peptone test. L = Acid and gas, lactose peptone test. N = Greenish-yellow fluorescence neutral red broth test.						REMARKS.
1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	
1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	
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...	...	...	...	...	...	...	...	+	−	...	...	...	...	...	...	...	N R +	
...	...	...	...	...	...	...	...	+	−	...	...	...	...	...	...	...	N R +	
...	...	...	...	...	...	...	...	+	−	...	..	...	...	...	...	...	N R +	
...	...	...	...	...	...	...	...	+	−	...	...	...	...	...	...	...	N R +	
...	...	...	...	...	...	...	...	+	−	...	...	...	...	...	..	...	N R +	
...	...	...	...	...	...	...	..	+	−	...	...	...	...	...	...	...	N R +	
...	...	...	...	...	...	...	...	+	−	...	...	...	...	...	...	...	N R +	
...	...	..	...	...	...	...	...	...	+	--	...	...	...	...	...	N R +	N R −	
...	...	...	..	...	..	...	+	−	...	...	...	...	...	...	...	N R +	N R −	
...	...	...	...	...	...	...	...	+	−	...	.	...	...	...	..	N R +	N R −	
...	...	...	...	...	...	...	..	+	−	...	...	...	...	...	...	N R +	N R −	
...	...	...	+	−	...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	+	−	...	...	..	...	...	...	...	...	...	...	B +	−	...	*Sample 3.* *Gas Test.* 24 hours: + ·01 c.c., − ·001 c.c. 48 hours: + ·001 c.c., − ·0001 c.c. *Litmus Milk Modified Test.* 48 hours: + ·00001 c.c.
..	...	...	...	...	...	...	+	−	...	...	...	...	..	...	...	...	N R +	
...	...	...	...	...	+	...	...	...	...	...	..	...	...	...	...	...	−	

24 samples at 100,000
14 samples at 10,000
13 samples at 1,000 } per c.c.
2 samples less than 1,000
2 samples less than 10

2 samples, + ·001 c.c., − ·0001 c.c.
13 samples, + ·01 c.c., − ·001 c.c.
5 samples, + ·1 c.c., − ·01 c.c.

Bile Salt Glucose Peptone Test.

10 samples at 100,000
7 samples at 10,000
10 samples at 1,000 } per c.c.
2 samples at 100

Lactose Peptone Test.

8 samples at 100,000
4 samples at 10,000 } per c.c.
1 samples at 1,000

Neutral Red Broth Test.

13 samples at 100,000
6 samples at 10,000 } per c c.

Gas Test.

The samples examined varied between :—
(*a*) examined after 24 hours
+ ·1 c.c., − ·01 c.c.
+ ·001 c.c., − ·0001 c.c.
(*b*) examined after 48 hours
+ ·001 c.c., − ·0001 c.c.
+ ·0001 c.c., − ·00001 c.c.

Litmus Milk Modified Test.

4 samples, + ·00001 c.c.
3 samples, + ·0001 c.c. − ·00001 c.c.

RESULTS OF THE BACTERIOLOGICAL EXAMINATION

1						2		3						4			
DESCRIPTION OF THE SAMPLE.						Total Number of Bacteria in 1 c.c.		Number on B. Coli (or closely allied forms) in 1 c.c.						Chief Biological Characters of the *strain* of B. Coli. present in the number specified in Col. 3.			
No.	Time of Collection.				Other Details.	Gelatine 20° C.	Agar at 37° C.	1	10	100	1,000	10,000	100,000	Gas. (Gelatine "shake" cultures, 24 hrs. at 20° C.)	Indol. (Broth Cultures 5 days at 37° C.)	(a) Acidity. (b) Clot. (Litmus milk cultures, 5 days at 37° C.)	
	Hour.	Day.	Month.	Year.				1 c.c.	.1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.			(a)	(b)
1	4.45 p.m.	13	3	1902	Chemically precipitated Sewage.	950,000	190,000	...	..	...	...	...	+	+	+	+	−
2	10.50 a.m.	19	3	"	do. do.	960,000	160,000	...	...	...	+	...	...	+	+	+	+
3	9.45–10.15 a.m.	29	4	"	do. do.	200,000	29,000	...	...	...	+	...	...	+	+	+	+
4	4.0 p.m.	9	5	"	do. do.	1,700,000	170,000	...	...	...	...	...	+	+	+	+	+
5	4.0 p.m.	13	5	"	do. do.	1,900,000	360,000	...	...	..	+	...	...	+	+	+	+
6	4.45-5.0 p.m.	22	5	"	do. do.	9,300,000	860,000	...	..	...	...	...	+	+	−	+	+
7	3.0–3.15 p.m.	23	5	"	do. do.	11,000,000	1,400,000	...	...	...	...	...	+	+	−	+	+
8	3.30 p.m.	4	6	"	do. do.	11,000,000	6,600,000	...	...	...	...	...	+	+	+	−	−
9	4.30 p.m.	5	6	"	do. do.	18,000,000	6,400,000	...	...	...	...	...	+	+	−	+	+
10	3.15 p.m.	9	6	"	do. do.	24,000,000	7,500,000	...	...	...	...	+	...	+	+	+	+
11	12.20 p.m.	11	6	"	do. do.	2,100,000	160,000	...	...	...	+	...	...	+	−	+	+
12	4.45 p.m.	12	6	"	do. do.	29,000,000	17,000,000	...	...	...	...	...	+	+	−	+	+
13	4.0 p.m.	16	6	"	do. do.	30,000,000	7,200,000	...	..	...	...	...	+	+	−	+	+
14	4.15–4.30 p.m.	17	6	"	do. do.	22,000,000	6,000,000	...	...	...	...	+	...	+	−	−	−
15	5.0 p.m.	21	7	"	do. do.	10,000,000	4,300,000	...	...	...	...	...	+	+	−	+	+
16	4.50 p.m.	23	7	"	do. do.	22,000,000	8,000,000	...	...	...	...	...	+	+	−	+	+
(281) 17	—	20	8	"	do. do.	—	—	...	...	...	...	...	...	...	...	...	...
(282) 18	—	27	8	"	do. do.	—	—	...	...	...	...	...	...	...	...	...	...
(283) 19	—	16	9	"	do. do.	—	—	...	...	...	...	...	...	...	...	...	..
(284) 20	12.0 noon	23	9	"	do. do.	20,000,000	5,300,000	...	...	...	+	...	...	No records.			
(285) 21	1.0 p.m. 5.0 p.m.	26	9	"	do. do.	23,000,000	11,000,000	...	...	...	...	+	...	+	+	−	−
22	4.30 p.m.	3	10	"	do. do.	7,000,000	1,800,000	...	...	...	...	...	+	+	+	+	+
23	5.0 p.m.	7	10	"	do. do.	16,000,000	10,000,000	...	...	...	..	...	+	+	−	+	−
24	5.0 p.m.	21	10	"	do. do.	8,000,000	1,200,000	...	...	...	...	...	+	+	−	+	+
25	2.30 p.m.	28	10	"	do. do.	10,000,000	3,000,000	...	...	...	...	+	...	+	+	+	+
26	5.0 p.m.	17	11	"	do. do.	3,000,000	980,000	...	...	...	...	+	...	+	−	−	−
27	4.30–5.0 p.m.	21	11	"	do. do	2,900,000	620,000	...	...	...	+	...	...	+	+	+	+
28	11.50 a.m.	26	11	"	do. do.	—	1,200,000	...	...	...	...	...	+	+	−	+	−
29	3.35 p.m.	2	12	"	do. do.	5,000,000	60,000	...	...	...	−	...	...	−	...	...	..
30	3.4 p.m.	8	12	"	do. do.	3,000,000	170,000	...	...	...	...	...	+	No records.			
					Average per c.c.	11,231,153	3,765,148	15 Samples at 100,000, 5 Samples at 10,000, 6 Samples at 1,000 per c.c. 1 Sample less than 1,000 per c.c.						8 out of 24 produced both indol and clot. 4 out of 24 produced neither indol nor clot. 9 out of 24 produced clot but no indol. 3 out of 24 produced indol but not clot.			

OF MANCHESTER SEWAGE CHEMICALLY PRECIPITATED.

5						6						7						8
INDOL TEST. Indol in broth cultures direct (5 days at 37° C.)						B. ENTERITIDIS SPOROGENES TEST. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						OTHER TESTS. B=Acid and gas, bile salt, glucose peptone test. L=Acid and gas, lactose peptone test. N.R.=Greenish-yellow fluorescence neutral red broth test.						REMARKS.
1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	
1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	
...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	+	−	...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	+	−	...	...	...	...	...	...	...	...	...	...	...	..	...	
...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	B +	−	
...	...	...	+	−	...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	B +	...	
...	...	...	...	..	+	...	...	...	...	...	..	...	...	...	...	B +	−	
...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	B +	−	
...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	B +	
...	...	...	..	...	+	...	...	...	...	...	...	...	...	...	...	B +	−	
...	...	...	+	−	...	...	...	...	...	...	...	...	...	...	B −	...	...	
...	...	...	...	+	−	...	...	...	...	...	...	...	...	...	...	B +	−	
...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	B +	
...	...	...	...	+	−	...	...	...	...	...	...	...	..	...	...	B +	−	
...	...	...	...	...	+	...	..	...	...	...	...	...	...	...	...	B +	L +	
...	...	...	...	...	+	...	...	...	...	...	...	..	...	...	...	L +	−	
...	...	...	...	...	..	...	...	...	...	...	...	...	...	...	...	...	N R +	
...	...	...	...	...	...	..	..	+	−	...	...	...	...	...	...	...	N R +	
...	...	..	...	...	...	...	...	+	−	...	...	...	...	...	...	N R +	−	
...	...	...	+	−	...	...	+	−	...	...	...	...	..	...	B +	N R +	−	
..	...	...	...	+	−	...	+	−	...	...	...	...	...	...	...	...	B +	
...	...	...	..	...	+	...	...	...	...	...	...	...	...	...	...	B L +	−	
...	...	...	...	+	−	...	...	...	...	...	..	...	...	...	...	B +	L +	
...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	B +	
...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	B +	L +	−	
...	...	...	+	−	...	...	...	...	...	...	...	...	...	...	L +	−	...	
...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	+	−	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	−	...	...	...	...	...	...	..	...	...	...	...	...	...	...	
...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	...	

REMARKS:

Gas Test.

Samples (282) (283) (284) gave results as follows :—

24 hours.
(282) + ·001 c.c., − ·0001 c.c.
(283) + ·001 c.c , − ·0001 c.c.
(284) + ·1 c.c., − ·01 c.c.

48 hours.
(282) + ·00001 c.c.
(283) + ·00001 c.c.
(283) + ·001 c.c. − ·0001 c.c.

Litmus Milk Modified Test.

Samples (282) (283) (284) gave respectively results as follows :—

+ ·00001 c.c. ; + ·00001 c.c.
+ ·001 c.c. − ·0001 c.c.

Sample (285) gave result as follows, as regards *Gas Test* :—

(*a*) 24 hours.
+ 1 c.c., − ·1 c.c.

(*b*) 48 hours.
+ ·1 c.c., − ·01 c.c.

Summary (Indol Test):

15 Samples at 100,000 }
5 Samples at 10,000 } per c.c.
6 Samples at 1,000 }
1 Sample less than 1,000 per c.c.

Summary (B. Enteritidis Sporogenes Test):

2 Samples + ·01 c.c., − ·001 c.c.
2 Samples + ·1 c.c., − ·01 c.c.

Summary (Other Tests):

Bile Salt Glucose Peptone Test.
4 Samples at 100,000 }
10 Samples at 10,000 } per c.c.
2 Samples at 1,000 }
1 Sample less than 1,000.

Lactose Peptone Test.
2 Samples at 100,000 }
3 Samples at 10,000 } per c.c.
1 Sample at 1,000 }

Neutral Red Broth Test.
2 Samples at 100,000 }
2 Samples at 10,000 } per c.c.

Summary (Remarks):

Gas Test.
The samples examined varied between :—
(*a*) Examined after 24 hours.
+ 1 c.c. − ·1 c.c.
+ ·001 c.c., − ·0001 c.c.
(*b*) Examined after 48 hours.
+ ·1 c.c. − ·01 c.c.
+ ·00001 c.c.

Litmus Milk Modified Test.
2 Samples + ·00001 c.c.
1 Sample + ·001 c.c., − ·0001 c.c.

RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF THE EFFLUENTS

1						2		3						4			
DESCRIPTION OF THE SAMPLE.						Total Number of Bacteria in 1 c.c.		Number of B. Coli (or closely allied forms) in 1 c.c.						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection. Hour.	Day.	Month.	Year.	Other Details.	Gelatine at 20° C.	Agar at 37° C.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	Gas. (Gelatine "shake" cultures 24 hrs. at 20° C.)	Indol. (Broth cultures, 5 days at 37° C.)	(a) Acidity. (Litmus milk cultures, 5 days at 37° C.)	(b) Clot. (Litmus milk cultures, 5 days at 37° C.)
1	4.30 p.m.	13	3	1902	Effluent from No. 2A. ½-acre bed.	170,000	7,500	...	+	...	...	...	...	+	+	+	+
2	4.30 p.m. 5 p.m.	2	5	,,	do. do. (end of discharge)	3,800,000	510,000	...	...	...	...	...	+	+	–	+	+
3	4 p.m.	6	5	,,	do. do.	1,800,000	90,000	...	...	...	+	...	...	+	–	+	+
4	4 p.m.	9	5	,,	do. do. (end of discharge)	8,800,000	280,000	...	...	...	...	+	...	+	–	–	–
5	3.15 p.m. 3.30 p.m.	19	5	,,	do. do. (drainings)	3,400,000	760,000	...	...	...	...	+	...	+	–	+	+
6	3.15 p.m.	9	6	,,	do. do.	3,100,000	360,000	...	...	...	...	...	+	+	–	+	–
7	4.45 p.m.	12	6	,,	do. do.	7,400,000	2,900,000	...	...	..	...	+	...	+	+	–	–
8	11.30 a.m.	19	9	,,	do. do. (commencement of discharge).	2,800,000	660,000	...	...	...	...	+	...	+	–	+	+
9	12 noon 1 p.m.	23	9	,,	do. do. (drainings)	5,500,000	1,500,000	...	...	...	...	+	...	+	+	+	+
10	11 a.m.	10	10	,,	do. do. (about half empty)	5,700,000	560,000	...	...	...	...	...	+	+	–	+	–
11	...	14	10	,,	do. do. (end of discharge)	1,000,000	840,000	...	...	...	...	+	..	+	–	+	+
12	11 a.m.	17	10	,,	do. do. (three-quarters full)	210,000	100,000	...	...	...	...	...	+	+	–	–	–
13	3.10 p.m.	29	1	1903	do. do. (end of discharge)	800,000	30,000	...	...	...	–	...	...	...	...	...	...
14	4.30 p.m.	30	1	,,	do. do. (drainings)	3,000,000	1,000,000	...	...	...	–	...	...	...	...	...	...
15	12.40 p.m.	20	2	,,	do. do. (half discharged)	540,000	110,000	...	...	...	+	...	...	+	No R	ecor	ds.
16	11.45 a.m.	18	3	1902	Effluent from No. 1 ½-acre bed.	1,300,000	140,000	...	...	...	+	...	...	+	–	–	–
17	4 p.m.	16	6	,,	do. do.	6,900,000	1,200,000	..	...	...	...	...	+	+	–	+	+
18	4.15 p.m. 4.30 p.m.	17	6	,,	do. do.	9,800,000	2,300,000	...	...	...	...	...	+	+	–	+	+
19	5 p.m.	21	7	,,	do. do.	1,900,000	640,000	...	...	...	...	+	...	+	+	+	+
20 (117)	...	20	8	,,	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
21 (118)	4.5 p.m.	27	8	,,	do. do. (at end of discharge).	...	...	...	...	...	...	...	...	...	...	...	..
22 (119)	3.20 p.m.	2	9	,,	do. do. (bed ½ empty).	...	...	...	...	...	...	...	...	...	...	...	...
23 (120)	...	16	9	,,	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
24	3.15 p.m.	19	9	,,	do. do.	1,400,000	280,000	...	...	...	...	...	+	+	–	+	+
25	4.15 p.m.	19	9	,,	do. do.	840,000	250,000	...	...	...	–	...	...	...	...	...	...
26	4.30 p.m.	3	10	,,	do. do.	6,100,000	770,000	...	...	...	...	+	...	+	–	+	+
27	2.45 p.m.	10	10	,,	do. do.	5,100,000	440,000	...	...	...	...	...	+	+	–	+	+
28	5 p.m.	21	10	,,	do. do.	4,100,000	220,000	...	...	...	+	..	...	+	–	+	+
29	4.15 p.m. 4.30 p.m.	12	11	,,	do. do.	8,400,000	240,000	...	...	...	...	...	+	+	No R	ecor	ds.
30	2.30 p.m.	19	11	,,	do. do.	2,900,000	540,000	...	...	...	...	+	...	+	–	+	+
31	3.25 p.m.	2	12	,,	do. do.	3,000,000	680,000	...	...	...	...	...	+	+	–	+	–
32	3.4 p.m.	...	...		do. do.	6,400,000	350,000	...	...	...	...	...	+	+	–	+	+
33	10.30 a.m.	29	1	1903	do. do.	1,200,000	110,000	..	...	...	–	...	...	...	...	...	...
34	2.40 p.m.	13	2	,,	do. do.	460,000	52,000	...	...	...	...	+	...	+	–	+	+
35	3.45 p.m.	19	2	,,	do. do.	1,200,000	52,000	...	..	...	+	...	...	+	+	+	+
36 (169)	4.40 p.m.	5	8	1902	Effluent from No. 7. ½-Acre Bed.	...	...	...	...	...	...	...	...	...	...	...	...
37	...	12	8	,,	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
38	5. 0 p.m.	22	10	,,	do. do. (half empty)	3,300,000	450,000	...	...	...	+	...	...	+	–	+	+
39	2.30 p.m.	23	,,	,,	do. do. (drainings)	500,000	460,000	...	...	...	...	...	+	+	–	+	–
40	3.30 p.m.	14	11	,,	do. do. (drainings)	3,600,000	700,000	...	...	...	...	...	+	+	–	+	–

FROM MATURE HALF-ACRE PRIMARY CONTACT BEDS AT MANCHESTER.

5						6						7					
INDOL TEST. Indol in broth cultures direct (5 days at 37° C.)						B. ENTERITIDIS SPOROGENES TEST. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						OTHER TESTS. B. = Acid and gas, bile salt glucose peptone test. L. = Acid and gas, lactose peptone test. N.R. – Greenish-yellow fluorescence, neutral red broth test.					
1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000
1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.
...	+	−	...	...	...	..	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	+	−	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	+	−	...	...	...	...	...	...	...	...	...	B +	−	...
...	...	...	...	+	−	...	...	...	...	..	...	...	...	...	...	B +	−
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REMARKS.

Gas Test.

Samples (117), (118), (119), (120), gave results as follows :—

24 hours.

(117) + ·01 c.c., − ·001 c.c.
(118) + ·001 c.c., − ·0001 c.c.
(119) + ·01 c.c., − ·001 c.c.
(120) + ·1 c.c., − ·01 c.c.

48 hours.

+ ·0001 c.c., − ·00001 c.c.
+ ·0001 c.c., − ·00001 c.c.
+ ·0001 c.c., − ·00001 c.c.
+ ·001 c.c., − ·0001 c.c.

Litmus Milk Modified Test.

Samples (117), (118), (119), (120) gave results as follows :—

+ ·00001 c.c. ;
+ ·0001 c.c. − ·00001 c.c.
+ ·00001 c.c.
+ ·0001 c.c., − ·00001 c.c.

Gas Test.

Sample 36 (169) gave in 24 hours results as follows :—
+ 1 c.c., — ·1 c.c.

Litmus Milk Modified Test.

Samples (169) and (170) gave results respectively as follows :—
+ ·0001 c.c. − ·00001 c.c., and
+ ·00001 c.c.

RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF THE EFFLUENTS

No	Description of the Sample (1): Time of Collection: Hour	Day	Month	Year	Other Details	Total Number of Bacteria in 1 c.c. (2): Gelatine at 20° C.	Agar at 37° C.	Number of B. Coli (or closely allied forms) in 1 c.c. (3): 1 (1 c.c.)	10 (·1 c.c.)	100 (·01 c.c.)	1,000 (·001 c.c.)	10,000 (·0001 c.c.)	100,000 (·00001 c.c.)	Chief Biological Characters of the strain of B. coli present in the Number specified in Col. 3 (4): Gas. (Gelatine "shake" cultures, 24 hrs. at 20° C.)	Indol. (Broth cultures, 5 days at 37° C.)	(a) Acidity. (Litmus milk cultures, 5 days at 37° C.)	(b) Clot.
41	4. 0 p.m.	24	11	1902	Effluent from No. 7 $\frac{1}{2}$-acre bed (first flush)	No Record	1,500,000	...	...	...	...	...	+	+	–	+	+
42	4. 0 p m.	2	12	,,	do. do. (first flush)	2,300,000	220,000	...	...	...	...	...	+	+	–	+	–
43	3. 0 p.m.	12	12	,,	do. do. (drainings)	8,200,000	1,300,000	...	...	...	...	...	+	+	–	+	–
44	2 35 p.m.	5	2	1903	do. do. (first flush)	4,100,000	1,600,000	...	...	+	...	...	...	+	–	+	–
45	3.30 p m.	5	2	,,	do. do. (drainings)	...	1,300,000	...	...	...	–	...	...	...	...	...	...
46	9.45 a.m.	13	2	,,	do. do. (drainings)	1,000,000	100,000	...	...	...	...	...	+	+	–	+	+
47	10. 0 a.m.	19	9	1902	do. do. (three-quarter empty)	8,800,000	1,700,000	...	...	...	...	...	+	+	–	+	+
48	11.17 a.m.	30	1	,,	do. do. (half empty)	3,300,000	1,300,000	...	...	...	+	...	...	+	–	+	–
49	11.15 a.m.	3	2	,,	do. do. (half empty)	2,500,000	160,000	...	...	...	+	..	...	+	–	+	+
50	10. 0 a.m.	13	2	,,	do. do. (quarter empty)	2,200,000	320,000	...	...	...	...	+	...	+	–	–	–
51	10.45 a.m.	20	2	,,	do. do. (rather more than half discharged)	700,000	150,000	...	...	...	+	...	...	+	No Records.		
52	3.15-3.30 p.m.	19	5	1902	Effluent from No. 8. $\frac{1}{2}$ acre Bed.	4,100,000	1,000,000	...	...	...	...	+	...	+	–	+	+
53	8.30-8.45 p.m.	25	5	,,	do. do. (drainings)	12,000,000	1,200,000	...	...	...	...	...	+	+	–	+	+
54	3.30 p.m.	30	5	,,	do. do.	12,000,000	740,000	...	...	...	...	...	+	+	–	+	+
55	12.20 p m.	11	6	,,	do. do.	11,000,000	750,000	...	...	...	...	...	+	+	+	+	+
56 (151)	1 p.m. 12 noon–1 p.m.	23	9	,,	do. do. (first discharge)	7,100,000	2,200,000	...	...	...	...	+	...	+	+	+	+
57	5 p.m.	26	9	,,	do. do. (draining)	4,800,000	1,300,000	...	..	...	...	...	+	+	–	+	+
58	5.30 p.m.	30	9	,,	do. do. (first flush)	3,400,000	1,000,000	...	...	...	...	...	+	+	–	+	–
59	1.30 p.m.	10	10	,,	do. do.	5,600,000	310,000	...	...	...	...	+	...	+	–	+	+
60	..	14	10	,,	do. do. ($\frac{3}{4}$ empty)	...	380,000	...	...	...	...	+	...	+	–	+	–
61	2.30 p.m.	19	11	,,	do. do. (end of discharge)	4,100,000	500,000	...	...	...	+	...	...	+	–	+	–
62	4.30–5 p.m.	21	11	,,	do. do. ($\frac{1}{2}$ empty)	9,100,000	1,100,000	...	...	..	...	...	+	+	–	+	–
63	4 p.m.	24	11	,,	do. do. (end of discharge)	...	550,000	...	...	...	...	+	...	+	–	+	–
64	3.25 p.m.	2	12	,,	do. do. (drainings)	2,100,000	600,000			No Records.				No Records.			
65	3–4 p.m.	8	12	,,	do. do. (draining)	7,000,000	840,000	...	...	...	..	...	+	+	No Records.		
66	3 p.m.	12	12	,,	do. do. (first flush)	14,000,000	2,000,000	...	...	...	...	...	+	+	No Records.		
67	10.55 a.m.	29	1	1903	do. do. (end of discharge)	500,000	20,000	...	...	–	...	...	...	...	No Records.		
68	4.30-5 p.m.	25	4	1902	Effluent from No. 1a $\frac{1}{2}$ acre bed (drainings) - - - - -	130,000	96,000	...	...	...	...	+	...	+	–	+	+
69	4 p.m.	6	5	,,	do. do.	1,600,000	810,000	...	...	...	...	+	..	+	+	+	+
70	4 p.m.	13	5	,,	do. do.	6,300,000	210,000	...	...	...	...	+	...	+	+	+	+
71	4.45–5 p.m.	22	5	,,	do. do.	13,000,000	1,400,000	...	...	...	...	...	+	+	–	+	–
72	3.15 p.m.	9	6	,,	do. do.	3,800,000	300,000	...	...	...	...	+	...	+	–	+	+
73	11.30 a.m.	19	9	,,	do. do. ($\frac{1}{2}$ empty)	1,200,000	...	...	...	...	...	+	...	+	–	+	+
74	10.30 a.m.	10	10	,,	do. do. (5 minutes after opening exit valve)	3,700,000	320,000	...	...	...	...	+	...	+	–	+	–
75	10 a.m.	17	10	,,	do. do. ($\frac{1}{4}$ full).	110,000	40,000	...	...	+	...	...	...	+	–	+	+
76	12 noon.	20	11	,,	do. do. (drainings).	...	1,000,000	...	...	...	...	...	+	+	–	+	–
77	4.5 p.m.	3	2	1903	do. do. ($\frac{3}{4}$ empty).	...	34,000	...	...	...	+	...	...	+	–	+	–
78	11.45 a.m.	20	2	,,	do. do. ($\frac{2}{3}$ discharge).	...	19,000	...	...	..	+	...	...	+	No Records.		
					No. 4 $\frac{1}{2}$ Acre Bed.												
79	4. 0 p.m.	4	12	1902	Effluent from No. 4 $\frac{1}{2}$ Acre Bed. (first flush).	6,000,000	2,900,000	...	...	...	...	...	+	+	–	+	–

'ROM MATURE HALF-ACRE PRIMARY CONTACT BEDS AT MANCHESTER—*continued.*

5						6						7						8
INDOL TEST. Indol in broth cultures direct (5 days at 37° C.)						B. ENTERITIDIS SPOROGENES TEST. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						OTHER TESTS. B. = Acid and gas, bile salt glucose peptone test. L. = Acid and gas, lactose peptone test. N. R. = Greenish-yellow fluorescence, neutral red broth test.						REMARKS.
1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	
1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	
...	...	...	...	+	−	...	...	...	...	...	...	...	...	...	..	..	...	Sample 151 gave results as regards Gas test :
...	...	...	...	+	−	...	...	...	...	..	...	...	...	...	..	...	...	(*a*) 24 hours.
...	...	...	+	−	...	...	...	...	..	...	...	...	...	...	..	...	...	+ ·1 c.c. − ·01 c.c.
...	...	...	...	+	−	...	...	...	...	...	...	...	...	...	..	...	...	(*b*) 48 hours.
...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	..	...	...	+ ·0001 c.c. − ·00001 c.c.
...	..	...	+	−	...	...	..	...	...	...	...	...	...	...	..	...	...	*Litmus Milk Modified Test.*
...	..	...	...	...	+	...	...	..	...	..	...	...	...	...	..	B L +	-	+ ·00001 c.c.
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RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF THE EFFLUENTS

1						2		3						4			
DESCRIPTION OF THE SAMPLE.						Total Number of Bacteria in 1 c.c.		Number of B. Coli (or closely allied forms) in 1 c.c.						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection. Hour.	Day.	Month.	Year.	Other Details.	Gelatine at 20° C.	Agar at 37° C.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	Gas. (Gelatine "shake" cultures, 24 hrs. at 20° C.)	Indol. (Broth cultures, 5 days at 37° C.)	(a) Acidity.	(b) Clot. (Litmus milk cultures, 5 days at 37° C.)
																(a)	(b)
80	4.15-4.30 p.m.	12	12	1902	Effluent from No. 4 ½ Acre Bed (¼ empty)	3,700,000	420,000	...	...	...	...	+	...	+	–	+	+
					No. 5 ½ Acre Bed.												
81	11.5 a.m.	26	11	"	Effluent from No. 5 ½ Acre Bed (end of discharge)		1,000,000	...	...	...	...	+	...	+	–	+	–
82	3.55 p.m.	19	12	"	Effluent from No. 5 ½ Acre Bed (about ¼ discharged)	3,100,000	38,000	...	...	...	+	...	..	+	+	+	+
					No. 9 ½ Acre Bed.												
83	3.30 p.m.	14	11	"	Effluent from No. 9 ½ Acre Bed (first discharge)	8,600,000	1,600,000	...	...	...	...	...	+	+	+	+	–
					No. 3 ½ Acre Bed.												
84	5. 0 p.m.	23	10	"	Effluent from No. 3 ½ Acre Bed (¼ empty)	1,900,000	250,000	...	...	...	+	...	...	+	–	+	+
					No. 6 ½ Acre Bed.												
85	3.40 p.m.	20	2	1903	Effluent from No. 6 ½ Acre Bed (½ discharged)	790,000	550,000	...	...	...	...	...	+	+	No	reco	rd.
86 (10)	...	8	9	"	½ Acre Filtrate, average of 6 acre plot, towards end of discharge	...	...	...	...	...	...	...	...	...	...	...	...
87 (19)	3.30-4.15 p.m.	14	9	"	½ Acre Bed average filtrate, 6 acre plot	...	...	...	...	...	...	...	...	...	...	...	...
88 (46)	...	19	10	"	½ Acre Filtrate, 6 acre plot Series II.	...	...	...	...	...	...	...	...	...	...	...	...
89 (50)	...	26	10	"	½ Acre Filtrate, 6 acre plot (Series II.)	...	...	...	...	...	...	...	...	...	...	...	...
90 (59)	...	23	11	"	Filtrate from 6 acre plot (average)	...	...	...	...	...	...	...	...	...	...	...	...
91 (68)	...	7	12	"	Filtrate from 6 acre plot Series II.	...	...	...	...	...	...	...	...	..	...	...	...
92 (72)	3-3.30 p.m.	13	12	"	Filtrate from 6 acre plot Series II. (average)	...	...	...	...	...	...	...	...	...	...	...	...
93 (11)	...	8	9	"	½ Acre Filtrate average of 20 acre plot	...	...	...	...	...	...	...	...	...	...	...	...
94 (32)	...	27	9	"	½ Acre Bed Filtrate (20 acre plot) 15 minutes after opening valve.	...	...	...	...	...	...	...	...	...	...	...	...
95 (42)	...	10	10	"	½ Acre Bed Filtrate (average 20 acre plot, Series I.	...	..	...	...	...	...	...	...	...	...	...	...
96 (54)	2.15-4 p.m.	15	11	"	Half Acre (20 acres east, average)	..	...	...	...	...	..	...	...	...	...	...	...
97 (64)	3.30-4 p.m.	29	11	"	Filtrate from 20 acre plot (average)	...	...	...	...	...	...	...	...	...	...	...	...
98 (69)	4.30 p.m.	7	12	"	Filtrate from 20 acre plot, Series I.	..	...	...	...	...	...	...	...	...	...	...	...
99 (73)	3-3.30 p.m.	13	12	"	Filtrate from 20 acre plot, Series 1. (average)	...	..	...	...	...	...	...	...	...	...	...	...
100 (6)	...	3	9	"	½ Acre Bed Filtrate	...	...	...	...	...	..	...	...	...	...	..	...
101 (26)	2.30-3.30 p.m.	20	9	"	½ Acre Bed Filtrate channels beginning to discharge	...	..	...	...	...	...	...	...	...	...	...	...
					Averages per c.c. Samples 1 to 85 (inclusive) were derived from *individual beds* (Nos. 2a, 1, 7, 2, 8, 1a, 4, 5, 9, 3, and 6) in contra-distinction to samples 86 to 101 (inclusive) which were derived chiefly from (6 acre and 20 acre) plots of beds.]	4,227,464	701,391	31 samples at 100,000 per c.c. 24 samples at 10,000 per c.c. 14 samples at 1,000 per c.c. 2 samples at 100 per c.c. 1 sample at 10 per c.c. 5 samples less than 1,000 per c.c. 1 sample less than 100 per c.c.						9 out of 65 produced both indol and clot 25 out of 65 produced neither indol nor clot 29 out of 65 produced clot but no indol 2 out of 65 produced indol but no clot			
					Averages per c.c. inclusive of all the results).												

FROM MATURE HALF-ACRE PRIMARY CONTACT BEDS AT MANCHESTER—*continued.*

5						6						7						8
INDOL TEST. Indol in broth cultures direct (5 days at 37° C.)						B. ENTERITIDIS SPOROGENES TEST. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						OTHER TESTS. B.=Acid and gas, bile salt glucose peptone test. L.=Acid and gas, lactose peptone test. N.R.=Greenish-yellow fluorescence neutral red broth test.						REMARKS.
1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10 000	100,000	
1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	
...	...	...	...	+	−	...	..	...	..	...	...	...	...	...	...	...	L +	
...	...	...	+	−	...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	+	..	..	...	...	...	...	..	...	...	...	...	...	...	..	
...	...	...	...	...	+	...	...	..	...	...	...	...	...	...	...	...	L +	
...	..	...	...	+	−	...	...	...	...	...	...	...	...	...	B +	...	...	
...	...	...	+	..	...	...	...	...	...	...	...	...	...	...	..	...	...	
...	..	...	...	...	...	...	+	−	...	...	...	..	...	...	...	N R +	−	
...	...	...	...	...	...	..	+	−	...	...	...	...	...	...	..	..	N R +	
...	...	...	...	...	...	...	+	−	...	...	...	...	...	...	...	...	N R +	
...	...	...	...	...	...	...	+	−	...	...	...	...	...	...	...	...	N R +	
...	...	...	...	...	...	...	...	+	−	...	...	...	...	...	..	...	N R +	
...	...	...	...	...	...	...	+	−	...	...	...	...	...	..	N R +	−	...	
...	...	...	...	...	...	+	−	...	...	...	...	...	...	...	N R +	−	...	
...	...	...	...	...	...	...	...	+	−	...	...	...	...	...	...	...	N R +	
..	...	...	...	...	...	...	...	+	−	...	...	...	...	...	...	...	N R +	
...	...	...	...	...	...	...	+	−	..	...	...	...	...	...	...	...	N R +	
...	...	...	...	...	...	...	+	−	...	...	...	...	..	..	...	N R +	−	
...	...	...	...	...	...	...	+	−	...	...	...	...	...	...	...	N R +	−	
...	...	...	...	...	...	...	+	−	...	...	...	..	...	...	N R +	−	...	
...	...	...	...	...	...	...	+	−	...	...	...	...	...	..	...	N R +	−	
...	...	...	...	...	...	...	+	−	...	...	...	...	...	...	...	...	N R +	
...	...	...	...	...	...	...	..	+	−	...	...	...	...	...	...	...	N R +	

Column 5 (Indol Test):

23 samples at 100,000 per c.c.
29 samples at 10,000 per c.c.
16 samples at 1,000 per c.c.
5 samples at 100 per c.c.
1 sample at 10 per c.c.
5 samples less than 1,000 per c.c.

Column 6 (B. enteritidis sporogenes Test):

2 samples + ·01 c.c., − ·001 c.c.
5 samples + ·1 c.c., − ·01 c.c.

6 samples + ·01 c.c., − ·001 c.c.
16 samples + ·1 c.c., − ·01 c.c.
1 sample + 1 c.c., − ·1 c.c.

Column 7 (Other Tests):

Bile Salt Glucose Peptone Test.
12 samples at 100,000 per c.c.
12 samples at 10,000 per c.c.
11 samples at 1,000 per c.c.
1 sample less than 1,000 per c.c.

Lactose Peptone Test.
6 samples at 100,000 per c.c.
8 samples at 10,000 per c.c.
2 samples at 1,000 per c.c.
1 sample at 100 per c.c.
1 sample less than 1,000 per c.c.

Neutral Red Broth Test.
3 samples at 100,000 per c.c.
3 samples at 10,000 per c.c.

Neutral Red Broth Test.
12 samples at 100,000 per c.c.
7 samples at 10,000 per c.c.
3 samples at 1,000 per c.c.

Column 8 (Remarks):

Gas Test.

The samples tested varied between :—

(*a*) 24 hours.
+1 c.c., − ·1 c.c.
+ ·001 c.c., − ·0001 c.c.

(*b*) 48 hours.
+ ·001 c.c., − ·0001 c.c.
+0001 c.c., − 00001 c.c.

Litmus Milk Modified Test.

4 samples + ·00001 c.c.
3 samples + ·0001 c.c., − ·00001 c.c.

RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF THE EFFLUENTS

1						2		3						4			
DESCRIPTION OF THE SAMPLE.						Total number of Bacteria in 1 c c.		Number of B. Coli (or closely allied forms) in 1 c.c.						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection.				Other Details.	Gelatine at 20° C.	Agar at 37° C.	1	10	100	1,000	10,000	100,000	Gas. (Gelatine "shake" cultures, 24 hrs. at 20° C.)	ndol. (Broth cultures, (5 days at 37° C.)	(a) Acidity. (b) Clot. (Litmus milk cultures (5 days at 37° C.)	
	Hour.	Day.	Month.	Year.				1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.			(a)	(b)
1	4.30 p.m.	25	4	1902	Effluent from No. 2, ½ Acre Bed	1,300,000	78,000	...	...	...	...	+	...	+	+	+	+
2	4 p.m.	9	5	,,	Effluent from No. 7, ½ Acre Bed	9,500,000	870,000	...	...	...	...	+	..	+	−	+	+
3	4 p.m.	13	5	,,	Effluent from No. 9, ½ Acre Bed	6,600,000	720,000	...	...	...	...	+	...	+	+	+	+
4	4.45 p.m.	22	5	,,	Effluent from No.10, ½ Acre Bed	21,000,000	2,500,000	...	...	...	...	...	+	+	−	+	+
5	3.30 p.m.	4	6	,,	Effluent from No. 9, ½ Acre Bed	16,000,000	2,100,000	...	...	...	...	...	+	+	−	+	+
6	4.30 p.m.	5	6	,,	Effluent from No. 7, ½ Acre Bed (Drainings)	2,700,000	330,000	...	..	...	...	...	+	+	−	+	+
7	4.45 p.m.	12	6	,,	Effluent from No. 3, ½ Acre Bed	12,000,000	3,100,000	...	...	...	...	...	+	+	+	+	+
8	4 p.m.	16	6	,,	Effluent from No. 7, ½ Acre Bed (commencement of discharge)	7,600,000	1,400,000	...	..	..	...	...	+	+	−	−	−
9	4.15 to 4.30 p.m.	17	6	,,	Effluent from No. 7, ½ Acre Bed	12,000,000	3,400,000	...	...	...	...	..	+	+	−	+	+
10	4.45 p.m.	29	1	1903	Effluent from No.13, ½ Acre Bed (first time of filling, 24 hours contact)	1,500,000	35,000	...	...	...	—	...	...	..	.	...	...
11	3.30 to 4.15 p.m.	14	9	1904	Filtrate from No.71, ½ Acre Bed (5 minutes after opening exit valve) New Bed worked at present with 24 hours contact	...	...	...	..	...	.	...	...	...	...	...	..
12	24 hours contact	20	9	,,	Filtrate from No.73, ½ Acre Bed (New Bed 5 minutes after opening valves)	...	...	...	...	...	...	...	...	...	...	...	...
13	...	27	9	,,	Filtrate from No.80, ½ Acre Bed (Channel 9)	...	...	...	..	..	...	...	...	...	..	...	...
14	...	5	10	,,	Filtrate from ½ Acre Beds Series III. (New Beds)	..	...	...	...	...	...	..	...	...	...	...	...
15	...	10	10	,,	Filtrate from ½ Acre Bed (at end of discharge) Series III. New Beds worked 6 hours contact	...	...	..	...	...	...	...	...	...	...	...	...
16	...	19	10	,,	Filtrate from ½ Acre Beds, New Beds 6 hours contact at end of discharge	...	...	...	...	...	...	...	...	...	...	...	...
					Averages per c.c.	9,020,000	1,453,300	6 samples at 100,000 per c.c. 2 samples at 10,000 per c.c. 1 sample at 1,000 per c.c. 1 sample less than 1,000 per c.c.						3 out of 9 produced both indol and clot. 1 out of 9 produced neither indol nor clot. 5 out of 9 produced clot but no indol.			

FROM NEW (NOT MATURE) PRIMARY CONTACT HALF-ACRE BEDS AT MANCHESTER.

5						6						7						8
INDOL TEST. Indol in broth cultures direct (5 days at 37° C.)						B. ENTERITIDIS SPOROGENES TEST. Spores of B. enteritidis sporogenes (Klien's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						OTHER TESTS. B. = Acid and gas, bile salt glucose peptone test. N.R. = Greenish-yellow fluorescence, neutral red broth test.						REMARKS.
1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	
1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	
...	...	...	...	+	−	..	...	...	...	...	...	...	...	...	...	...	...	
...	...	+	−	...	...	...	...	...	...	...	...	...	...	...	B +	−	...	
..	...	...	...	+	−	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	+	...	...	...	...	...	...	...	..	...	...	...	B +	
...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	B +	
...	...	...	+	−	...	...	..	...	...	...	...	...	...	...	...	B +	−	
...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	B +	−	
...	..	...	...	+	−	...	...	...	...	...	...	...	...	...	...	B +	−	
...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	B +	
...	...	+	−	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	+	−	...	...	...	...	...	...	...	...	...	N R +	
...	...	...	...	...	...	..	+	−	...	...	...	...	...	...	...	...	N R +	
...	...	...	...	..	...	...	+	−	...	...	...	...	...	...	...	N R +	−	
...	...	...	...	...	...	+	−	...	...	...	...	...	...	...	...	...	N R +	
...	..	...	...	...	...	...	+	−	...	..	...	...	...	...	...	...	N R +	
...	...	...	...	...	...	...	+	−	...	...	...	..	...	...	...	...	N R +	
4 samples at 100,000, 3 samples at 10,000, 1 sample at 1,000, 2 samples at 100 } per c.c.						4 samples + ·1 c.c., − ·01 c.c. 2 samples + 1 c.c., − ·1c.c.						*Bile Salt Glucose Peptone Test.* 3 samples at 100,000, 3 samples at 10,000, 1 sample at 1,000 } per c.c. *Neutral-Red Broth Test.* 5 samples at 100,000, 1 sample at 10,000 } per c c.						

RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF THE EFFLUENTS

1						2		3						4			
DESCRIPTION OF THE SAMPLE.						Total Number of Bacteria in 1 c.c.		Number of B. Coli (or closely allied forms) in 1 c.c.						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection. Hour.	Day.	Month.	Year.	Other Details.	Gelatine at 20° C.	Agar at 37° C.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100 000 / ·00001 c.c.	Gas. (Gelatine "shake" cultures 24 hrs. at 20° C.)	Indol. (Broth cultures, 5 days at 37° C.)	(a) Acidity. (Litmus milk cultures, 5 days at 37° C.)	(b) Clot. (Litmus milk cultures, 5 days at 37° C.)
					BED A.											(a)	(b)
1	4.30-5 p.m.	25	4	1902	Effluent from Bed A.	170,000	24,000	...	...	...	...	...	...	...	...	...	...
2	—	12	8	,,	,, ,, ,,	...	...	...	...	...	...	...	...	...	...	...	...
3 (210)	—	20	8	,,	,, ,, ,, Expl.	...	...	...	...	...	...	...	...	...	...	...	...
4 (211)	—	27	8	,,	,, ,, ,,	...	...	...	...	...	...	...	...	...	...	...	...
5 (212)	—	16	9	,,	,, ,, ,,	...	...	...	...	..	...	...	...	...	...	...	...
6	2.45 p.m.	10	10	1902	,, ,, ,, (Just after 1st discharge.)	3,100,000	200,000	...	...	...	...	+	...	+	–	+	+
7	3. 0 p.m.	17	10	,,	,, ,, ,, (¾ discharged.)	1,200,000	240,000	...	...	...	+	...	...	+	–	+	–
8	2.45 p.m.	23	10	,,	,, ,, ,, (¼ discharged.)	6,600,000	1,100,000	...	...	...	+	...	...	+	+	+	+
9	2.45 p.m.	28	10	,,	,, ,, ,, (¼ empty.)	4,700,000	500,000	...	...	...	...	..	+	+	—	+	–
10	3.15 p.m.	2	12	,,	,, ,, ,, (½ empty.)	650,000	60,000	...	...	...	+	...	...	+	–	+	+
11	3.45 p.m.	4	12	,,	,, ,, ,, (½ empty.)	3,600,000	870,000	..	...	...	...	...	+	+	–	+	+
12	2.45 p.m.	17	11	,,	,, ,, ,, (¼ discharged.)	3,200,000	720,000	...	...	...	...	+	...	+	–	+	–
13	—	19	11	,,	,, ,, ,, (5 minutes after opening exit valve.)	4,500,000	1,500,000	...	...	...	...	+	...	+	–	+	+
					Averages per c.c.	3,091,111	579,333	2 samples at 100,000 / 3 samples at 10,000 / 3 samples at 1,000 per c.c.						1 out of 8 produced both indol and clot. 3 out of 8 produced neither indol nor clot. 4 out of 8 produced clot but no indol.			
					BED B.												
(58)	9.30-10 a.m.	1	5	1902	Effluent from Bed B. (after long period.)	5,500	200	...	...	+	...	..	...	+	–	–	–
(265)	—	12	12	,,	*Town's water taken for measurement of capacity taken at end of discharge.*	...	[7000]	...	...	...	...	...	...	...	...	...	...
					BED C.												
1	11. 0 a.m.	18	3	1902	Effluent from Bed C. (last drainings)	220,000	19,000	...	...	+	...	...	...	+	–	–	–
2	10.35 a.m.	19	3	,,	,, ,, ,, (first discharge).	8,100,000	210,000	...	...	..	...	+	...	+	–	+	+
3	11.5 a.m.	3	2	1903	,, ,, ,,	...	40,000	...	.	...	+	...	...	+	+	+	+

ROM EXPERIMENTAL PRIMARY BEDS (A, B, and C) AT MANCHESTER.

5						6						7						8
INDOL TEST. Indol in broth cultures direct (5 days at 37° C.)						B. ENTERITIDIS SPOROGENES TEST. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						OTHER TESTS. B. = Acid and gas bile salt glucose peptono test. L. = Acid and gas,l actose peptone test. N.R. = Greenish-yellow fluorescence neutral red broth test.						REMARKS.
	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	
c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·00i c.c.	·0001 c.c.	·00001 c.c.	
.	..	...	+	–	...	...	...	...	..	...	...	...	...	...	...	...	...	*Gas Test.* Samples (210), (211), (212) yielded results as follows:— 24 hours. 210) + ·01 c.c., – ·001 c.c.; 211) + ·01 c.c., – ·001 c.c.; 212) + ·1 c.c., – ·01 c.c.; 48 hours. 210) + ·0001 c.c., – ·00001 c.c. 211) + ·0001 c.c., – ·00001 c.c. 212) + ·001 c.c., – ·0001 c.c. *Litmus Milk Modified Test.* Samples (209), (210), (211), (212) gave respectively results as follows: + ·00001c.c.; + 0001 c.c., – ·00001 c.c.; + ·0001 c.c., – ·00001 c.c.; + 00001 c.c.
.	...	...	...	...	...	...	+	–	...	...	...	..	...	...	...	N R +		
.	...	...	...	...	.:.	...	...	+	–	...	...	...	...	...	...	N R +	–	
	...	...	...	...	...	...	+	–	...	...	...	...	...	...	...	N R +	–	
.	...	...	...	...	...	...	...	+	–	...	...	...	...	...	...	N R +	–	
.	...	...	...	+	–	...	...	...	...	...	...	...	...	...	B +	–	...	
.	...	...	...	+	–	...	...	...	...	...	...	...	..	...	B L +	–	...	
..	...	...	...	...	+	...	...	...	...	...	...	...	..	...	B +	L +	...	
.	...	...	...	+	–	...	...	...	...	...	...	...	...	...	...	B +	L +	
..	...	...	+	–	...	...	...	...	...	...	...	...	...	...	...	...	...	
..	...	...	...	+	–	...	...	...	...	...	...	...	...	...	...	...	...	
..	..	...	...	...	+	...	...	..	...	...	...	...	...	...	L +	–	...	
..	...	+	–	...	...	...	...	...	..	...	...	...	...	...	...	+	–	
2 samples at 100,000 4 samples at 10,000 2 samples at 1,000 1 sample at 100 per c.c.						2 samples + ·01 c.c., – ·001 c.c. 2 samples + ·1 c.c., – ·01 c.c.						*Bile Salt Glucose Peptone Test.* 1 sample at 10,000 3 samples at 1,000 per c.c. *Lactose Peptone Test.* 1 sample at 100,000 2 samples at 10,000 2 samples at 1,000 per c.c. *Neutral Red Broth Test.* 4 Samples at 10,000 per c.c.						*Gas Test.* The samples examined varied between :— (a) examined after 24 hours. + ·1c.c., – ·01 c.c., + ·01 c.c., – ·001 c.c. (b) examined after 48 hours. + ·001c.c., – ·0001 c.c., + ·0001 c.c., – ·00001 c.c. *Litmus Milk Modified Test.* 2 Samples + ·00001 c.c. 2 Samples + ·0001c.c., – ·00001 c.c.
.	+	–	...	...	...	...	...	...	...	...	...	..	...	..	...	...	...	
..	...	...	[+	–]	...	...	...	...	...	...	...	..	...	...	...	..	...	
..	...	+	–	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
..	...	...	...	+	–	...	...	...	...	...	...	...	...	...	...	...	...	
..	...	+	–	...	.	...	...	...	...	...	...	..	...	...	...	.	...	

RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF THE

1						2		3						4			
DESCRIPTION OF THE SAMPLE.						Total Number of Bacteria in 1 c.c.		Number of B. Coli (or closely allied forms) in 1 c.c.						Chief Biological Characters of the *strain* of B coli present in the number specified in col. 3.			
No.	Time of Collection. Hour.	Day.	Month.	Year.	Other details.	Gelatine at 20° C.	Agar at 37° C.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	Gas. (Gelatine "shake" cultures, 24 hrs. at 20° C.)	Indol. (Broth cultures, 5 days at 37° C.)	(a) Acidity. (b) Clot. (Litmus milk cultures, 5 days at 37° C.) (a)	(b)
1	5.15 p.m.	10	3	1902	Effluent from Bed D.	130,000	11,000	...	...	...	...	+	−	+	+	−	−
2	11.0 a.m.	18	3	,,	do. do.	280,000	50,000	...	..	...	+	...	..	+	+	+	+
3	4.30-5 p.m.	25	4	,,	do. (first flush) do.	39,000	5,600	...	...	+	...	...	...	+	−	+	−
4 (229)	...	12	8	,,	do. do.	...	...	...	...	...	..	...	...	...	...	...	...
5 (230)	...	20	8	,,	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
6 (231)	4.0 p m.	27	8	,,	do. Expl. do.	...	...	..	..	...	...	..	...	..	...	...	...
7 (232)	3.25 p.m.	2	9	,,	do. do.	...	...	..	...	...	...	...	...	..	..	...	...
8 (233)	...	16	9	,,	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
9	4.15 p.m.	19	9	,,	do. do.	1,600,000	1,300,000	...	...	...	−	..	...	...	...	...	...
10	5.30 p.m.	30	9	,,	do. (drainings) do.	2,100,000	1,200,000	...	...	...	...	...	+	+	−	+	+
11	3.0 p.m.	17	10	,,	do. do.	580,000	240,000	...	...	...	+	...	...	+	−	+	−
12	2.45 p.m.	23	10	,,	do. (¾ discharge) do.	4,600,000	1,000,000	...	...	...	+	...	...	+	−	+	−
13	2.45 p.m.	28	10	,,	do. (¼ discharge) do.	1,300,000	280,000	...	...	...	+	...	...	+	+	+	+
14	3.30 p.m.	14	11	,,	do. do.	460,000	32,000	...	...	..	...	+	−	+	−	+	·
15	2.45 p.m.	17	11	,,	do. do.	800,000	300,000	...	...	...	...	+	...	+	+	+	−
16	2.40 p.m.	19	11	,,	do. do.	1,300,000	330,000	...	...	...	...	+	...	+	−	+	−
17	3.15 p.m.	2	12	,,	do. do.	440,000	80,000	...	...	...	+	...	...	+	−	+	−
18	11.5 a.m.	3	2	1903	do. do.	...	20,000	...	...	...	−	...	...	...	...	...	...
					Averages per c.c.	1,135 750	372,969	1 sample at 100,000, 4 samples at 10,000, 5 samples at 1,000, 1 sample at 100 } per c.c. 2 samples less than 1,000 per c.c.						2 out of 11 produced both indol and clot. 6 out of 11 produced neither indol nor clot. 1 out of 11 produced clot but no indol. 2 out of 11 produced indol but no clot.			

EFFLUENTS FROM EXPERIMENTAL SECONDARY BED D AT MANCHESTER.

5						6						7					
INDOL TEST. Indol in broth cultures direct (5 days at 37° C.)						B. ENTERITIDIS SPOROGENES TEST. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						OTHER TESTS. B. = Acid and gas, bile salt glucose peptone test. L. = Acid and gas, lactose peptone test. NR = Greenish yellow fluorescence, neutral red broth test.					
1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000
1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.
...	...	...	...	+	−	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	+	−	...	...	...	...	...	...	...	...	...	...	...	...	...
...	...	..	+	−	...	...	...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	+	−	...	...	...	..	..	...	..	N R +	−
...	...	...	...	...	...	...	+	−	...	...	...	...	...	...	...	...	N R +
...	...	...	...	...	...	...	+	−	..	...	...	...	...	...	...	N R +	−
...	...	...	..	...	...	+	−	...	...	...	...	...	...	...	...	N R +	−
...	...	...	...	...	...	...	...	+	−	..	...	...	...	...	...	N R +	−
...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	B +	L +	−
...	...	...	...	...	+	...	...	...	...	...	...	...	..	...	...	...	B L +
...	..	...	...	+	−	...	...	...	...	...	...	...	...	...	B L −	...	...
...	..	...	...	...	+	...	...	...	...	...	...	...	...	...	B +	L +	−
..	...	...	+	−	...	...	...	...	..	...	...	...	...	...	B +	−	L +
...	...	...	...	+	−	...	...	...	...	...	...	...	...	..	...	L +	−
...	...	...	+	−	..	...	...	...	...	..	...	..	...	...	...	L +	—
..	...	+	−	...	...	...	...	..	...	...	...	...	...	...	L +	−	...
...	..	+	−	...	...	...	...	...	...	...	...	...	...	...	...	...	...
...	...	+	−	...	...	...	..	..	...	...	...	..	...	...	...	...	...

3 samples at 100,000, 3 samples at 10,000, 4 samples at 1,000, 3 samples at 100 } per c.c.

1 sample + ·01 cc., − ·001 cc.
3 samples + ·1 cc., − ·01 cc.
1 sample + ·1 cc., − ·1 cc.

Bile Salt Glucose Peptone Test.

1 sample at 100,000, 3 samples at 1,000 } per c.c.
1 sample less than 1,000 per c.c.

Lactose Peptone Test.

2 samples at 100,000, 4 samples at 10,000, 1 sample at 1,000 } per c.c.
1 sample less than 1,000 per c.c.

Neutral Red Broth Test.

1 sample at 100,000, 4 samples at 10,000 } per c.c.

8 REMARKS.

Gas Test.

Samples (230), (231), (232), (233) gave results as follows :—

24 hours.
(230) + ·01 c.c., − ·001 c.c.
(231) + ·01 c.c., − ·001 c.c.
(232) + ·1 c.c., − ·01 c.c.
(233) + ·1 c.c., − ·01 c.c.

48 hours.
(230) + ·001 c.c., − ·0001 c.c.
(231) + ·0001 c.c., − ·00001 c.c.
(232) + ·01 c.c., − ·001 c.c.
(233) + ·001 c.c., − ·0001 c.c.

Litmus Milk Modified Test.

Samples (229), (230), (231), (232 (233) yielded results respectively as follows :—

+ ·0001 c.c., − ·00001 c.c.
+ ·0001 c.c., − ·00001 c.c.
+ ·0001 c c., − ·00001 c.c.
+ ·0001 c.c., − ·00001 c.c.
+ ·0001 c.c., − ·00001 c.c.

Gas Test.

The samples examined varied between :—

(*a*) examined after 24 hours.
+ ·1 c.c., − ·01 c.c.,
+ ·01 c.c., − ·001 c.c.

(*b*) examined after 48 hours.
+ ·01 c.c., − ·001 c.c.,
+ ·0001 c.c., − ·00001 c.c.

Litmus Milk Modified Test.

All 5 examples examined.
+ ·0001 c.c., − ·00001 c.c.

RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF THE

1						2		3						4			
DESCRIPTION OF THE SAMPLE.						Total Number of Bacteria in 1 c.c.		Number of B. Coli (or closely allied forms) in 1 c.c.						Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection. Hour.	Day.	Month.	Year.	Other Details.	Gelatine at 20° C.	Agar at 37° C.	1 / 1 c.c.	10 / ·1 c.c.	100 / ·01 c.c.	1,000 / ·001 c.c.	10,000 / ·0001 c.c.	100,000 / ·00001 c.c.	Gas. (Gelatine "shake" cultures, 24 hrs. at 20° C.	Indol. (Broth cultures, 5 days at 37° C.)	(a) Acidity. (Litmus milk cultures, 5 days at 37° C.)	(b) Clot. (Litmus milk cultures, 5 days at 37° C.)
																(a)	(b)
1	11 a.m.	18	3	1902	Effluent from Stoddart Filter	320,000	27,000	..	...	...	+	...	...	+	−	+	+
2	9.45 to 10.15 a.m.	29	4	,,	do. do.	No record	130,000	...	...	...	...	+	...	+	−	+	−
3	9.30 to 10 a.m.	1	5	,,	do. do.	1,400,000	100,000	...	...	...	...	...	+	+	−	+	+
4	3.15 to 3.30 p.m.	19	5	,,	do. do.	5,400,000	1,400,000	...	...	..	+	...	...	+	−	−	−
5	3.30 p.m.	4	6	,,	do. do.	9,100,000	1,500,000	...	...	...	...	+	...	+	−	+	+
6 (249)	...	12	8	,,	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
7 (250)	4.5 p.m.	27	8	,,	do. do.	..	...	...	...	...	...	...	...	...	...	...	...
8 (251)	3.35 p.m.	2	9	,,	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
9 (298)	2.40 p.m.	19	2	1903	do. do.	1,400,000	...	...	...	...	...	..	+	+	No Records		
10	...	8	9	1904	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
11	3.30 to 4.15 p.m.	14	9	,,	do. do.	...	...	...	...	...	...	...	...	...	...	...	...
								2 samples at 100,000 / 2 samples at 10,000 / 2 samples at 1,000 } per c.c.						3 out of 5 produced clot but no indol. 2 out of 5 produced neither indol nor clot.			
Roscoe Coke Filter.																	
1 (25)	4.45 p.m.	13	3	1902	Roscoe Coke Filter Effluent (after chemical treatment)	130,000	50,000	...	...	...	...	+	..	+	+	+	+
2 (43)	11 a.m.	10	3	,,	,,	900,000	52,000	...	−	...	...	...	...	...	...	...	...
3 (238)	11.20 a.m.	26	11	,,	,, ¼ empty	No record.	560,000	...	...	...	...	...	+	+	−	+	−
4 (7)	...	3	9	1904	Coke Bed Effluent (Roscoe experimental filter)	...	...	...	...	...	...	...	...	...	...	..	...
Roscoe Cinder Filter.																	
1 (26)	4.45 p.m.	13	3	1902	Roscoe Cinder Filter (after chemical treatment)	1,300,000	55,000	...	..	+	...	...	...	+	−	+	+
2 (42)	11 a.m.	19	3	,,	,,	1,100,000	52,000	...	−	...	...	..	...	...	...	...	...
3 (237)	11.20 a.m.	26	11	,,	,, ¼ empty	No record.	790,000	...	...	...	..	+	...	+	−	+	−
4 (4)	...	3	9	1904	Cinder Bed Effluent (Roscoe experimental filter)	...	...	...	...	...	...	...	..	...	...	...	...
Dunbar Filter.																	
1 (15)	4 to 4.30 p.m.	8	9	1904	Dunbar Filtrate (heavy rain in morning)	...	...	..	...	...	...	...	...	...	...	...	...
2 (23)	3.30 to 4.15 p.m.	14	9	,,	Dunbar Filtrate	..	...	...	...	...	...	...	...	...	...	...	...
Filtered Effluents.																	
1 (257, 22)	3.15 p.m.	11	3	1902	Filtered Effluent	7,000,000	1,400,000	...	...	...	...	...	+	+	−	+	−
2 (258, 241)	12 noon	28	11	,,	Filtered Effluent from No. 1 Bed	...	2,100,000	...	...	...	...	...	+	+	−	+	−
3 (259, 263)	3 to 4 p.m.	8	12	,,	Filtered Effluent from No. 5 Bed, ¼ empty	10,000,000	3,000,000	...	...	...	...	...	+	+	−	+	−
New Primary Beds.																	
(60)	...	23	11	1904	Filtrate from New Primary Beds (Drainings)	...	...	...	...	...	...	...	...	...	...	...	...

EFFLUENTS FROM THE STODDART FILTER AT MANCHESTER.

5 — INDOL TEST. Indol in broth cultures direct (5 days at 37° C.)						6 — B. ENTERITIDIS SPOROGENES TEST. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						7 — OTHER TESTS. B. = Acid and gas, bile salt glucose peptone test. N.R. = Greenish-yellow fluorescence, neutral red broth test.						8 — REMARKS.
1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	1 1 c.c.	10 ·1 c.c.	100 ·01 c.c.	1,000 ·001 c.c.	10,000 ·0001 c.c.	100,000 ·00001 c.c.	
...	..	...	+	–	...	...	...	...	...	...	...	...	...	...	...	...	...	*Litmus Milk Modified Test.* Samples (249), (250), (251) yielded results respectively as follows :— + ·0001 c.c., – ·00001 c.c. ; + ·0001 c.c., – ·00001 c.c. ; + ·00001 c.c. *Gas Test.* Samples (250) and (251) yielded results as follows :— 24 hours. (250) + ·01 c.c., – ·001 c.c. (251) + ·1 c.c., – ·01 c.c. 48 hours. (250) + ·001 c.c., – ·0001 c.c. (251) + ·001 c.c., – ·0001 c.c.
...	...	...	+	–	...	...	...	...	...	...	...	...	...	...	...	B +	–	
...	...	...	...	+	–	...	...	...	...	..	...	...	...	...	...	...	...	
...	...	...	...	+	–	...	...	...	...	...	...	...	...	B +	–	...	...	
...	...	...	...	+	–	...	...	...	...	...	...	...	...	...	...	...	B +	
...	...	...	...	...	...	...	...	+	–	...	...	...	...	...	...	N R +	–	
...	..	...	...	...	..	...	+	–	...	...	...	...	...	...	...	N R +	–	
...	...	...	...	...	...	...	+	–	...	...	...	...	...	...	...	...	N R +	
...	...	+	–	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	..	...	...	...	...	+	–	...	...	...	...	...	...	...	...	N R +	
...	...	...	...	...	...	...	...	+	–	...	...	...	...	...	...	...	N R +	
3 samples at 10,000 2 samples at 1,000 1 sample at 100 per c.c.						2 samples + ·01 c.c., – ·001 c.c. 3 samples + ·1 c.c., – ·01 c.c.						*Bile Salt Glucose Peptone Test.* 1 sample at 100,000 1 sample at 10,000 1 sample at 100 per c.c. *Neutral Red Broth Test.* 3 samples at 100,000 2 samples at 10,000 per c.c.						
...	...	...	...	+	–	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	+	..	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	+	–	...	...	...	...	...	...	...	N R +	–	
–	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	+	–	...	...	...	...	...	...	...	...	...	...	...	...	...	..	
...	...	...	+	–	...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	..	+	–	...	...	...	...	...	...	...	...	N R +	
...	...	...	...	...	...	...	+	–	...	...	...	...	...	...	...	...	N R +	
...	...	...	...	...	...	...	+	–	...	..	...	...	...	...	...	..	N R +	
...	...	...	+	–	...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	+	–	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	...	+	–	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	..	...	...	...	...	+	–	...	..	...	...	...	..	...	N R +	–	

RESULTS OF THE BACTERIOLOGICAL EXAMINATION OF THE

(*The majority of the samples were*

DESCRIPTION OF THE SAMPLE. STORM BEDS.						2 Total Number of Bacteria in 1 c.c.		3 Number of B. Coli (or closely allied forms) in 1 c.c.						4 Chief Biological Characters of the *strain* of B. Coli present in the number specified in Col. 3.			
No.	Time of Collection. Hour.	Day.	Month.	Year.	Other Details.	Gelatine at 20° C.	Agar at 37° C.	1 (1 c.c.)	10 (·1 c.c.)	100 (·01 c.c.)	1,000 (·001 c.c.)	10,000 (·0001 c.c.)	100,000 (·00001 c.c.)	Gas. (Gelatine "shake" cultures, 24 hours at 20° C.	Indol. (Broth cultures 5 days at 37° C.	(a) Acidity. (Litmus milk cultures, 5 days at 37° C.	(b) Clot.
1	5.30 p.m.	30	9	1902	Effluent from Storm Water Bed - -	10,000,000	2,600,000	..	...	...	...	...	+	+	−	+	+
2	5 p.m.	7	10	,,	Effluent from Storm Bed, Nos. 12 & 7.	5,300,000	1,400,000	...	..	...	...	+	...	+	−	+	−
3	—	28	,,	,,	Effluent from Storm Bed - - -	5,300,000	1,100,000	...	...	...	...	+	...	+	+	Alk.	+
4	5 p.m.	17	11	,,	Effluent from Storm Bed, No. 3 recent construction (first discharge) - -	2,900,000	800,000	...	..	...	+	...	...	+	+	+	−
5	5 p.m.	17	,,	,,	Effluent from Storm Bed, 8 and 12 (first discharge) -	390,000	68,000	...	...	...	+	...	...	+	−	+	+
6	4.30–5 p.m.	21	,,	,,	Effluent from Storm Bed (1st discharge)	5,900,000	600,000	...	...	...	+	...	...	+	−	+	−
7	3.35 p.m.	2	12	,,	Effluent from No. 12 Storm Bed (continuous flow) -	2,600,000	240,000	...	..	...	...	+	...	+	+	+	−
8	3.45 p.m.	,,	,,	,,	Effluent from Nos. 4, 5, & 6 Storm Beds (recently started)	4,700,000	1,700,000	...	...	+	...	...	...	+	+	+	+
9	2.30–3 p.m.	8	,,	,,	Effluent from Nos. 8 and 12 Storm Beds (1st flush) - -	2,300,000	340,000	...	...	...	...	+	...	+	−	+	−
10	3.25 p.m.	29	1	1903	Effluent from Nos. 8 and 12 Storm Beds	400,000	10,000	...	...	...	+	..	...	+	+	+	+
11	11.17 a.m.	30	1	,,	Effluent from Nos. 7, 8, 11, and 12 Storm Beds - - -	1,100,000	63,000	...	...	...	+	...	...	+	+	+	+
12	3.15 p.m.	3	2	,,	Effluent from No. 12 Storm Bed (half empty) - -	...	40,000	...	...	−	...	...	...	...	...	...	...
13	3.15 p.m.	,,	,,	,,	Effluent from No. 7 Storm Bed (first flush) - - -	...	61,000	...	...	...	+	...	...	+	−	+	+
14 (3)	—	3	9	1904	Storm Bed effluent Bed, ⅔ empty -	...	...	...	...	..	...	...	...	...	...	...	...
15 (13)	—	8	9	,,	Storm bed filtrate (average of easterly area) - - -	...	...	...	...	...	...	...	...	...	..	..	...
16 (20)	4.15 p.m.	14	9	,,	Storm bed filtrate, west area (first after opening exit valve) - - -	...	...	...	...	...	...	...	...	...	...	...	...
17 (27)	2.30–3.30 p.m.	20	9	,,	Filtrate from storm beds, westerly area	...	...	...	...	...	...	...	...	...	...	...	...
18 (34)	—	27	9	,,	Filtrate from storm beds (west area), 20 minutes after opening valve -	...	...	...	...	...	...	...	...	...	...	...	...
19 (51)	—	26	10	,,	Storm Bed filtrate (westerly area), at end of discharge -	...	...	..	...	...	...	...	...	...	...	...	...
20 (55)	2.15–4 p.m.	15	11	,,	Storm Bed, west average - -	...	...	...	...	...	...	...	...	...	...	...	.
21 (61)	—	23	11	,,	Filtrate from western area of storm beds (towards end of discharge) -	...	...	...	...	...	...	...	..	...	...	...	...
22 (65)	3.30–4 p.m.	29	11	,,	Filtrate from westerly area of storm beds (immediately after opening exit valve) - - -	...	...	...	...	...	...	...	...	...	...	...	...
					Averages per cc. -	3,717,272	694,000	1 sample at 100,000 per c.c. 4 samples at 10,000 per c.c. 6 samples at 1,000 per c.c. 1 sample at 100 per c.c. 1 sample less than 100 per c.c.						3 out of 12 produced both indol and clot. 3 out of 12 produced neither indol nor clot. 3 out of 12 produced clot but no indol. 2 out of 12 produced indol but no clot. 1 out of 12 produced alkali.			

EFFLUENTS OF THE STORM BEDS AT MANCHESTER.

not collected during wet weather.)

5						6						7						8
INDOL TEST. Indol in broth cultures direct (5 days at 37° C.)						B. ENTERITIDIS SPOROGENES TEST. Spores of B. enteritidis sporogenes (Klein's "enteritidis change" in anærobic milk cultures). Cultures heated to 80° C. for 10 minutes.						OTHER TESTS. B. = Acid and gas, bile salt glucose peptone test. L. = Acid and gas lactose peptone test. N.R. = Greenish-yellow fluorescence, neutral red broth test.						REMARKS.
1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	1	10	100	1,000	10,000	100,000	
1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	1 c.c.	·1 c.c.	·01 c.c.	·001 c.c.	·0001 c.c.	·00001 c.c.	
...	...	...	...	+	−	...	...	...	...	...	...	...	...	...	...	B +	L +	Samples 1 to 13 (inclusive) were derived from beds which, at the period at which these samples were taken, were dealing in dry weather mainly with chemical effluent. Samples 14 to 22 (inclusive) were derived from the same beds as samples 1 to 13, but the beds, during the period at which the samples 14 to 22 were taken, were dealing in dry weather with settled sewage. N.B. In time of storm the whole of the storm sewage (apart from that passing through the septic tanks) is passed through settling tanks and the storm beds deal with the effluent from these tanks.
...	...	...	...	...	+	...	...	...	...	...	...	...	...	.	...	B L +	−	
...	...	...	...	+	−	...	...	...	...	...	...	...	...	...	...	B +	L +	
...	...	...	...	+	−	...	...	...	...	...	...	...	..	...	L +	−	...	
...	...	...	+	−	...	...	...	...	...	...	...	...	...	...	...	L +	−	
...	...	...	+	−	...	..	...	...	...	...	...	..	...	...	.	...	...	
...	...	...	...	+	−	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	+	−	...	...	...	...	...	...	...	...	...	...	...	...	...	Wet weather.
...	...	...	...	...	+	...	...	...	...	...	...	...	...	...	...	..	...	
...	...	...	+	−	...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	+	−	...	...	...	...	...	...	...	...	...	...	...	...	...	
...	...	...	+	−	...	..	...	...	...	...	...	..	...	...	...	...	..	
...	...	+	−	...	...	...	...	...	..	...	...	...	...	...	...	...	...	
...	...	...	...	...	...	...	+	−	...	...	...	...	...	...	...	N R +	−	
...	...	...	...	...	...	...	+	−	...	...	...	...	...	...	...	...	N R +	Wet weather.
...	...	...	...	...	...	+	−	...	..	...	...	...	...	...	..	...	N R +	
...	...	...	..	...	...	...	+	−	...	...	...	...	...	...	...	N R +	−	
...	...	...	...	...	...	...	+	−	...	...	...	...	...	...	...	...	N R +	
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...	...	...	...	...	...	+	−	...	...	...	...	...	...	...	N R +	−	...	Wet weather.
...	...	...	...	...	...	+	−	...	...	...	...	...	...	...	...	N R +	−	
2 samples at 100,000 4 samples at 10,000 6 samples at 1,000 1 sample at 100 per c.c.						6 samples + ·1c.c., − ·01c.c. 3 samples + 1c.c., − ·1c.c.						*Bile Salt Glucose Peptone Test.* 3 samples at 10,000 per c.c. *Lactose Peptone Test.* 2 samples at 100,000 2 samples at 10,000 1 sample at 1,000 per c.c. *Neutral Red Broth Test.* 4 samples at 100,000 4 samples at 10,000 1 sample at 1,000 per c.c.						

MANCHESTER.

SUMMARY OF RESULTS.

SECTION I.

RAW AND SETTLED SEWAGE.

TOTAL NUMBER OF BACTERIA PER C.C.

(*a*) Gelatine at 20° C.
42 Samples.

Average Number 10,036,666 per c.c.
Greatest Number 32,000,000 „
Least Number 200,000 „
20 Samples (about 48 per cent.) contained at least 10 million per c.c.
19 Samples (about 45 „) „ „ 1 million „
3 Samples (about 7 „) „ „ 100,000 „

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester Raw and Settled Sewage.

Total number of bacteria (gelatine at 20°C.).

10 million ◆
◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ about 48 per cent.

1 million ◆
◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ about 45 per cent.

100,000 ◆ ◆ ◆ ◆ ◆ ◆ ◆ about 7 per cent.

(*b*) agar at 37° C.
48 Samples.

Average Number 2,379,625 per c.c.
Greatest Number 13,000,000 „
Least Number 32,000 „
1 sample (about 2 per cent.) contained at least 10 million per c.c.
31 samples (about 65 „) „ „ 1 million „
12 samples (about 25 „) „ „ 100,000 „
4 samples (about 8 „) „ „ 10,000 „

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester Raw and Settled Sewage.

Total number of bacteria (agar at 37° C.)

10 million ◆ ◆ about 2 per cent.

1 million ◆
◆ ◆
◆ ◆ ◆ ◆ about 65 per cent.

100,000 ◆ about 25 per cent.

10,000 ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ about 8 per cent.

Manchester Raw and Settled Sewage.

---

* B. COLI TEST.—Number of B. coli (or closely allied forms) in 1 c.c.
49 Samples.

33 Samples (about 67 per cent.) contained at least 100,000 per c.c.
9 Samples (about 18 „) „ „ 10,000 „
6 Samples (about 12 „) „ „ 1,000 „
18 Samples (about 2 „) „ less than 1,000 „

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester Raw and Settled Sewage.

B. Coli Test.

100,000 ◆
◆ ◆
◆ ◆ ◆ ◆ ◆ ◆ about 67 per cent.

10,000 ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ about 18 per cent.

1,000 ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ about 12 per cent.

About 2 per cent. negative result with $\frac{1}{1000}$ c.c.

With regard to the biological attributes of the B. coli or coli-like microbes isolated from the samples, about 26·6 per cent. were, on the basis of the tests employed, typical B. coli.

---

*As regards the B. coli, indol, bile salt glucose peptone, lactose peptone, neutral red broth and litmus milk modified tests, it is to be noted that the tests were not pushed beyond $\frac{1}{100000}$ c.c.

INDOL TEST.

49 Samples.

23 Samples (about 47 per cent.) contained at least 100,000 per c.c.
17 Samples (about 35 „) „ „ 10,000 „
9 Samples (about 18 „) „ „ 1,000 „

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester Raw and Settled Sewage.

Indol Test.

100,000 ◆
◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ about 47 per cent.
10,000 ◆
◆ ◆ ◆ about 35 per cent.
1,000 ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ about 18 per cent.

Manchester Raw and Settled Sewage.

B. ENTERITIDIS SPOROGENES TEST.

26 Samples.

10 Samples (about 38 per cent.) at least 1,000 per c.c. (+ ·001 c.c.)
16 „ (about 62 „) „ 100 „ (+ ·01 c.c.)

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester Raw and Settled Sewage.

B. Enteritidis Sporogenes Test.

1,000 ◆
◆ ◆ ◆ ◆ ◆ ◆ about 38 per cent.
100 ◆
◆ ◆
◆ about 62 per cent.

BILE SALT GLUCOSE PEPTONE TEST.

24 Samples.

11 Samples (about 46 per cent.) contained at least 100,000 per c.c.
9 Samples (about 37 „) „ „ 10,000 „
4 Samples (about 17 „) „ „ 1,000 „

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester Raw and Settled Sewage.

Bile Salt Glucose Peptone Test.

100,000 ◆
◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ about 46 per cent.
10,000 ◆
◆ ◆ ◆ ◆ ◆ about 37 per cent.
1,000 ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ about 17 per cent.

LACTOSE PEPTONE TEST.

11 Samples.

10 Samples (about 91 per cent.) contained at least 100,000 per c.c.
1 Sample (about 9 per cent.) „ „ „ 10,000 „ „

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester Raw and Settled Sewage.

Lactose Peptone Test.

100,000 ◆
◆ ◆
◆ ◆
◆ ◆ ◆ about 91 per cent.
10,000 ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ about 9 per cent.

NEUTRAL RED BROTH TEST.

26 Samples.

23 Samples (about 88 per cent.) contained at least 100,000 per c.c.
3 Samples (about 12 „) „ „ 10,000 „

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester Raw and Settled Sewage.

Neutral Red Broth Test.

100,000 ◆
◆ ◆
◆ ◆
◆ about 88 per cent.
10,000 ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ about 12 per cent.

Litmus Milk Modified Test.

6 Samples.

5 Samples contained at least 100,000 per c.c. (+·00001 c.c.)
1 Sample „ „ 10,000 „ (+·0001 c.c.)

Gas Test.

5 Samples.

a) 24 hours at 20° C.

2 Samples +·01 c.c., −·001 c.c.
2 Samples +·001 c.c., −·0001 c.c.
1 Sample +·0001 c.c., −·00001 c.c.

(*b*) 48 hours at 20° C.

2 Samples +·0001 c.c., −·00001 c.c.
3 Samples +·00001 c.c.

SECTION II.

SEPTIC TANK LIQUOR.

Total Number of Bacteria per c.c.

(*a*) Gelatine at 20° C. 49 samples.

Average Number 6,010,265 per c.c.
Greatest Number 18,000,000 „
Least Number 83,000 „

12 Samples (about 24 per cent.)	contained	at least	10 millions	per c.c.
30 Samples (about 61 „)	„	„	1 million	„
6 Samples (about 12 „)	„	„	100,000	„
1 Sample (about 2 „)	„	„	10,000	„

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester Septic Tank Liquor.

Total number of bacteria (gelatine at 20° C.).

10 million ✦ about 24 per cent.

1 million ✦
✦ ✦
✦ ✦ about 61 per cent.

100,000 ✦ ✦ ✦ ✦ ✦ ✦ ✦ ✦ ✦ ✦ ✦ ✦ about 12 per cent.

10,000 ✦ ✦ about 2 per cent.

(*b*) Agar at 37° C. 56 Samples.

Average Number 1,049,946 per c.c.
Greatest Number *8,300,000 „
Least Number 2,000 „

21 Samples (about 38 per cent.)	contained	at least	1 million	per c.c.
26 Samples (about 46 „)	„	„	100,000	„
8 Samples (about 14 „)	„	„	10,000	„
1 Sample (about 2 „)	„	„	1,000	„

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester Septic Tank Liquor.

Total number of bacteria (agar at 37° C.)

1 million ✦
✦ ✦ ✦ ✦ ✦ ✦ about 38 per cent.

100,000 ✦
✦ ✦ ✦ ✦ ✦ ✦ ✦ ✦ ✦ ✦ ✦ ✦ ✦ ✦ about 46 per cent.

10,000 ✦ ✦ ✦ ✦ ✦ ✦ ✦ ✦ ✦ ✦ ✦ ✦ ✦ ✦ about 14 per cent.

1,000 ✦ ✦ about 2 per cent.

B. Coli Test.—Number of B. coli (or closely allied forms) in 1 c.c.

56 Samples.

33 Samples (about 59 per cent.)	contained	at least	100,000	per c.c.
11 Samples (about 20 „)	„	„	10,000	„
8 Samples (about 14 „)	„	„	1,000	„
1 Sample (about 2 „)	„	„	100	„
1 Sample (about 2 „)	„	„	10	„
2 Samples (about 3 „)	„	less than	1,000	per c.c.

---

* When this sample was taken the tank had been recently re-started.

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester Septic Tank Liquor.

B. Coli Test.

100,000 ◆
◆ about 59 per cent.

10,000 ◆ about 20 per cent.

1,000 ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ about 14 per cent.

100 ◆ ◆ about 2 per cent.

10 ◆ ◆ about 2 per cent.

About 3 per cent. negative result with $\frac{1}{1000}$ c.c.

With regard to the biological attributes of the B. coli or coli-like microbes isolated from the samples, about 0 per cent. were, on the basis of the tests employed, typical B. coli.

INDOL TEST.

55 Samples.

24 Samples (about 44 per cent.) contained at least 100,000 per c.c.
14 Samples (about 25 „) „ „ 10,000 „
13 Samples (about 24 „) „ „ 1,000 „
2 Samples (about 3 „) contained less than 1,000 „
2 Samples (about 3 „) „ „ 10 „

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows:—

Manchester Septic Tank Liquor.

Indol Test.

100,000 ◆
◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ about 44 per cent.

10,000 ◆ about 25 per cent.

1,000 ◆ about 24 per cent.

About 3 per cent. negative $\frac{1}{1000}$ c.c.
About 3 per cent. negative $\frac{1}{10}$ c.c.

B. ENTERITIDIS SPOROGENES TEST.

20 Samples.

2 Samples (about 10 per cent.) contained at least 1,000 per c.c. (+·001 c.c.)
13 Samples (about 65 „) „ „ 100 „ (+ ·01 c.c.)
5 Samples (about 25 „) „ „ 10 „ (+ ·1 c.c.)

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester Septic Tank Liquor.

B. Enteritidis Sporogenes Test.

1,000 ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ about 10 per cent.

100 ◆
◆ ◆
◆ ◆ ◆ ◆ about 65 per cent.

10 ◆ about 25 per cent.

BILE SALT GLUCOSE PEPTONE TEST.

29 Samples.

10 Samples (about 34 per cent.) contained at least 100,000 per c.c.
7 Samples (about 24 „) „ „ 10,000 „
10 Samples (about 34 „) „ „ 1,000 „
2 Samples (about 7 „) „ „ 100 „

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester Septic Tank Liquor.

Bile Salt Glucose Peptone Test.

100,000 ◆
◆ ◆ ◆ about 34 per cent.

10,000 ◆ about 24 per cent.

1,000 ◆
◆ ◆ ◆ about 34 per cent.

100 ◆ ◆ ◆ ◆ ◆ ◆ ◆ about 7 per cent.

Lactose Peptone Test.

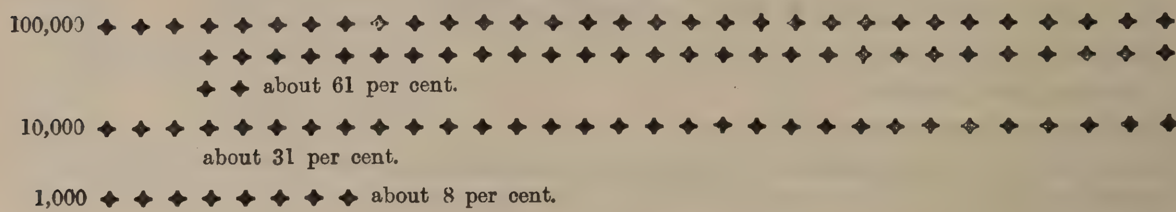
13 Samples.

8 Samples (about 61 per cent.) contained at least 100,000 per c.c.
4 Samples (about 31 „) „ „ 10,000 „
1 Sample (about 8 „) „ „ 1,000 „

These results may be illustrated by a diagram (each dot represents one per cent. of the samp es) as follows :-

Manchester Septic Tank Liquor.

Lactose Peptone Test.



Neutral Red Broth Test.

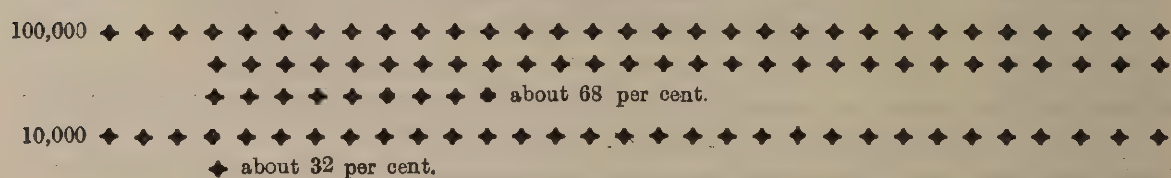
19 Samples.

13 Samples (about 68 per cent.) contained at least 100,000 per c.c.
6 Samples (about 32 „) „ „ 10,000 „

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester Septic Tank Liquor.

Neutral Red Broth Test.



Litmus Milk Modified Test.

7 Samples.

4 Samples contained at least 100,000 per c.c. (+·00001 c.c.)
3 „ „ 10,000 „ (+ ·0001 c.c.)

Gas Test.

5 Samples.

(*a*) 24 hours at 20° C.

1 Sample +·1 c.c. − ·01 c.c.
3 Samples +·01 c.c. − ·001 c.c.
1 Sample +·001 c.c. − ·0001 c.c.

(*b*) 48 hours at 20° C.

3 Samples +·001 c.c. − ·0001 c.c.
1 Sample +·0001 c.c. − ·00001 c.c.
1 Sample not examined.

SECTION III.

CHEMICALLY PRECIPITATED SEWAGE.

Total Number of Bacteria per c.c.

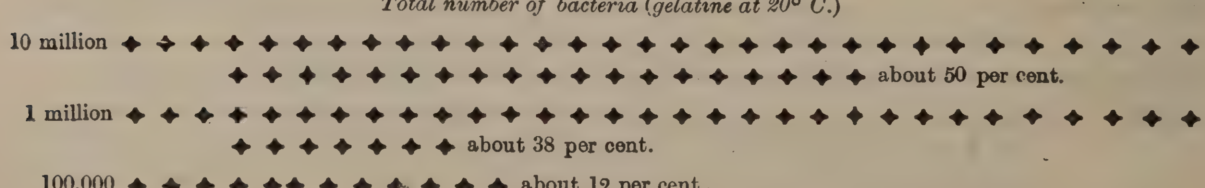
(*a*) Gelatine at 20° C. 26 Samples.

Average Number 11,231,153 per c.c.
Greatest Number 30,000,000 „
Least Number 200,000 „
13 Samples (about 50 per cent.) contained at least 10 million per c.c.
10 Samples (about 38 „) „ „ 1 million „
3 Samples (about 12 „) „ „ 100,000 „

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :-

Manchester sewage, chemically precipitated.

Total number of bacteria (gelatine at 20° C.)



(*b*) Agar at 37° C. 27 Samples.

Average Number	3,765,148 per c.c.	
Greatest Number	17,000,000 „	
Least Number	29,000 „	

3 Samples (about 11 per cent.) contained at least 10 million per c.c.
13 Samples (about 48 „) „ „ 1 million „
9 Samples (about 34 „) „ „ 100,000 „
2 Samples (about 7 „) „ „ 10,000 „

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :-

Manchester sewage chemically precipitated.

Total number of bacteria (agar at 37° C.)

10 million ◆◆◆◆◆◆◆◆◆◆◆ about 11 per cent.

1 million ◆◆ about 48 per cent.

100,000 ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ about 34 per cent.

10,000 ◆◆◆◆◆◆◆ about 7 per cent.

B. Coli Test. Number of B. coli (or closely allied forms) in 1 c.c.

27 Samples.

15 Samples (about 56 per cent.) contained at least 100,000 per c.c.
5 Samples (about 18 „) „ „ 10,000 „
6 Samples (about 22 „) „ „ 1,000 „
1 Sample (about 4 „) „ less than 1,000 in 1 c.c.

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester sewage, chemically precipitated.

B. Coli Test.

100,000 ◆◆ about 56 per cent.

10,000 ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ about 18 per cent.

1,000 ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ about 22 per cent.

About 4 per cent. negative result with $\frac{1}{1000}$ c.c.

With regard to the biological attributes of the B. coli or coli-like microbes isolated from the samples, about 33·3 per cent. were, on the basis of the tests employed, typical B. coli.

Indol Test.

27 Samples.

15 Samples (about 56 per cent.) contained at least 100,000 per c.c.
5 Samples (about 18 „) „ „ „ 10,000 „
6 Samples (about 22 „) „ „ „ 1,000 „
1 Sample (about 4 „) „ less than 1,000 „

The results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester sewage chemically precipitated.

Indol test.

100,000 ◆◆ about 56 per cent.

10,000 ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ about 18 per cent.

1,000 ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ about 22 per cent.

About 4 per cent negative result with $\frac{1}{1000}$ c.c.

B. Enteritidis Sporogenes Test.

4 Samples.

2 Samples contained at least 100 per c.c. (+ ·01 per c.c.)
2 Samples „ „ 10 „ (+ ·1 „

Bile Salt Glucose Peptone Test.

17 Samples.

4 Samples (about 23 per cent.) contained at least 100,000 per c.c.
10 Samples (about 59 „) „ „ 10,000 „
2 Samples (about 12 „) „ „ 1,000 „
1 Sample (about 6 „) „ less than 1,000 „

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester sewage chemically precipitated.

Bile salt glucose peptone test.

100,000 ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ about 23 per cent.

10,000 ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆
◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ about 59 per cent.

1,000 ◆◆◆◆◆◆◆◆◆◆◆◆ about 12 per cent.

About 6 per cent. negative result with $\frac{1}{1000}$ per c.c.

Manchester Sewage Chemically Precipitated.

Lactose Peptone Test.

6 Samples.

2 Samples contained at least 100,000 per c.c.
3 Samples „ „ 10,000 „
1 Sample „ „ 1,000 „

Neutral Red Broth Test.

4 Samples.

2 Samples contained at least 100,000 per c.c.
2 Samples „ „ 10,000 „

Litmus Milk Modified Test.

3 Samples.

2 Samples contained at least 100,000 per c.c. (+·00001 c.c.).
1 Sample „ „ 1,000 „ (+·001 c.c.).

Gas Test.

4 Samples.

(*a*) 24 hours at 20° C.

1 Sample + 1 c.c., —·1 c.c.
1 Sample + ·1 c.c., —·01 c. c.
2 Samples + ·001 c.c., —·0001 c.c.

(*b*) 48 hours at 20° C.

1 Sample + ·1 c.c., —·01 c.c.
1 Sample + ·001 c.c., —·0001 c.c.
2 Samples + ·00001 c.c.

SECTION IV.

EFFLUENTS FROM MATURE PRIMARY CONTACT HALF-ACRE BEDS.

Total Number of Bacteria per c.c.

(*a*) Gelatine at 20° C. 71 Samples.

Average Number 4,227,464 per c.c.
Greatest Number 14,000,000 „
Least Number 110,000 „
5 Samples (about 7 per cent.) contained at least 10,000,000
54 Samples (about 76 „) „ „ 1,000,000
12 Samples (about 17 „) „ „ 100,000

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester Mature Half-Acre Beds.

Total number of bacteria (gelatine at 20° C.)

10 millions ◆◆◆◆◆◆◆ about 7 per cent.

1 million ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆
◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆
◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ about 76 per cent.

100,000 ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ about 17 per cent.

(*b*) Agar at 37° C. 78 samples.

Average Number 701,391
Greatest Number 2,900,000
Least Number 7,500
23 Samples (about 30 per cent.) contained at least 1,000,000
44 Samples (about 56 „) „ „ 100,000
10 Samples (about 13 „) „ „ 10,000
1 Sample (about 1 „) „ „ 1,000

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester Mature Half-Acre Beds.

Total number of bacteria (agar at 37° C.)

1 million ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ about 30 per cent.

100,000 ◆◆ about 56 per cent.

10,000 ◆◆◆◆◆◆◆◆◆◆◆◆◆ about 13 per cent.

1,000 ◆ about 1 per cent.

B. Coli Test.—Number of B. Coli (or closely allied forms) per c.c.

78 samples.

31 Samples (about 40 per cent.)	contained	at least	100,000 per c.c
24 Samples (about 31 „)	„	„	10,000 „
14 Samples (about 18 „)	„	„	1,000 „
2 Samples (about 3 „)	„	„	100 „
1 Sample (about 1 „)	„	„	10 „
5 Samples (about 6 „)	„	less than	1,000 „
1 Sample (about 1 „)	„	„	100 „

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester Mature Half-Acre Beds

B. Coli Test.

100,000 ◆◆ about 40 per cent.

10,000 ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ about 31 per cent.

1,000 ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ about 18 per cent.

100 ◆◆◆ about 3 per cent.

10 ◆ about 1 per cent.

About 6 per cent. negative result with $\frac{1}{1000}$ c.c.
About 1 per cent. negative result with $\frac{1}{100}$ c.c.

With regard to the biological attributes of the B. coli or coli-like microbes isolated from the samples, about 13·8 per cent. were, on the basis of the tests employed, typical B. coli.

Indol Test.

79 Samples.

23 Samples (about 29 per cent.)	contained	at least	100,000 per c.c.
29 Samples (about 37 „)	„	„	10,000 „
16 Samples (about 20 „)	„	„	1,000 „
5 Samples (about 6 „)	„	„	100 „
1 Sample (about 1 „)	„	„	10 „
5 Samples (about 6 „)	„	less than	1,000 „

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester Mature Half-Acre Beds.

Indol Test.

100,000 ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ about 29 per cent.

10,000 ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ about 37 per cent.

1,000 ◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆◆ about 20 per cent.

100 ◆◆◆◆◆◆ about 6 per cent.

10 ◆ about 1 per cent.

About 6 per cent. negative result with $\frac{1}{1000}$ c.c.

B. Enteritidis Sporogenes Test.

23 Samples (including all the results).

6 Samples (about 26 per cent.)	contained	at least	100 per c.c.	(+·01 c.c)
16 Samples (about 70 „)	„	„	10 „	(+·1 c.c.)
1 Sample (about 4 „)	„	„	1 „	+1 c.c.)

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester Mature Half-Acre Beds.

B. Enteritidis Sporogenes Test.

100 ◆ about 26 per cent.

10 ◆
◆ ◆
◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ about 70 per cent.

1 ◆ ◆ ◆ ◆ about 4 per cent.

Bile Salt Glucose Peptone Test.

36 Samples.

12 Samples (about 33 per cent.) contained at least 100,000 per c.c.
12 Samples (about 33 „) „ „ 10,000 „
11 Samples (about 31 „) „ „ 1,000 „
1 Sample (about 3 „) „ less than 1,000 „

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester Mature Half-Acre Beds.

Bile Salt Glucose Peptone Test.

100,000 ◆
◆ ◆ about 33 per cent.

10,000 ◆
◆ ◆ about 33 per cent.

1,000 ◆
about 31 per cent.

About 3 per cent. negative result with $\frac{1}{1000}$ c.c.

Lactose Peptone Test.

18 Samples.

6 Samples (about 34 per cent.) contained at least 100,000 per c.c.
8 Samples (about 45 „) „ „ 10,000 „
2 Samples (about 11 „) „ „ 1,000 „
1 Sample (about 5 „) „ „ 100 „
1 Sample (about 5 „) „ less than 1,000 „

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester Mature Half-Acre Beds.

Lactose Peptone Test.

100,000 ◆
◆ ◆ ◆ about 34 per cent.

10,000 ◆
◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ about 45 per cent.

1,000 ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ about 11 per cent.

100 ◆ ◆ ◆ ◆ ◆ about 5 per cent.

About 5 per cent. negative result with $\frac{1}{1000}$ c. .

Neutral Red Broth Test.

22 Samples (inclusive of all the results).

12 Samples (about 54 per cent.) contained at least 100,000 per c.c.
7 Samples (about 32 „) „ „ 10,000 „
3 Samples (about 14 „) „ „ 1,000 „

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester Mature Half-Acre Beds.

Neutral Red Broth Test.

100,000 ◆
◆ about 54 per cent.

10,000 ◆
about 32 per cent.

1,000 ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ about 14 per cent.

Litmus Milk Modified Test.

7 Samples.

4 Samples contained at least 100,000 per c.c. (+ ·00001 c.c.)
3 „ „ „ 10,000 „ (+ ·0001 c.c.

Gas Test.

6 Samples.

(*a*) 24 hours at 20° C.

1 Sample + 1 c.c., —·1 c.c.
2 Samples + ·1 c.c., —·01 c.c.
2 Samples + ·01 c.c., —·001 c.c.
1 Sample + ·001 c.c., —·0001 c.c.

(*b*) 48 hours at 20° C.

1 Sample + ·001 c.c., —·0001 c.c.
4 Samples + ·0001 c.c., — ·00001 c.c.
1 Sample not examined.

SECTION V.

EFFLUENTS FROM NEW (NOT MATURE) PRIMARY CONTACT HALF-ACRE BEDS.

Total Number of Bacteria per c.c.

(*a*) Gelatine at 20° C.

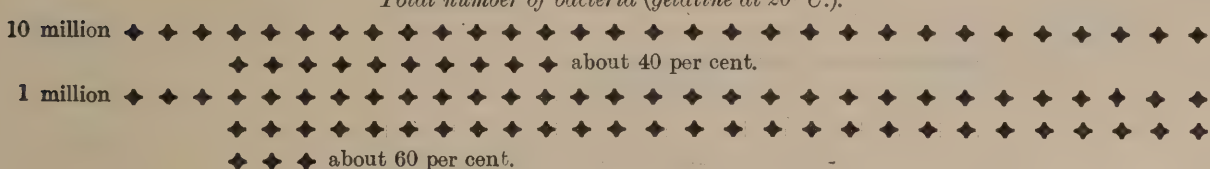
10 Samples.

Average Number 9,020,000 per c.c.
Greatest Number 21,000,000 „
Least Number 1,300,000 „
4 Samples (about 40 per cent.) contained at least 10 million per c.c.
6 Samples (about 60 „) „ „ 1 million „

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester New (not mature) Half-Acre Beds.

Total number of bacteria (gelatine at 20° C.).



(*b*) Agar at 37° C.

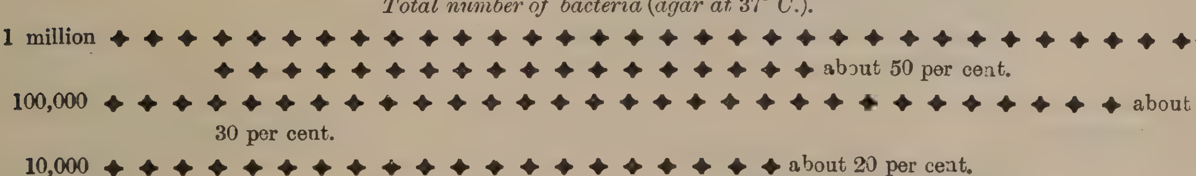
10 Samples.

Average Number 1,453,300 per c.c.
Greatest Number 3,400,000 „
Least Number 35,000 „
5 Samples (about 50 per cent.) contained at least 1,000,000 per c.c.
3 Samples (about 30 „) „ „ „ 100,000 „
2 Samples (about 20 „) „ „ „ 10,000 „

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester New (not mature) Half-Acre Beds.

Total number of bacteria (agar at 37° C.).



B. Coli Test.—Number of B. Coli (or closely allied forms) in 1 c.c.

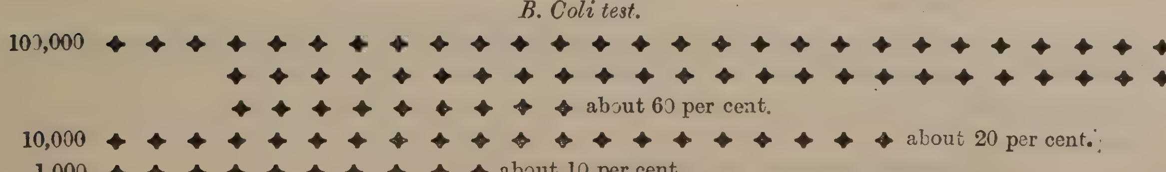
10 Samples.

6 Samples (about 60 per cent.) contained at least 100,000 per c.c.
2 Samples (about 20 „) „ „ 10,000 „
1 Sample (about 10 „) „ „ 1,000 „
1 Sample (about 10 „) „ less than 1,000 „

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester New (not mature) Half-Acre Beds.

B. Coli test.



About 10 per cent. negative result with $\frac{1}{1000}$c.c.

With regard to the biological attributes of the B. Coli or coli-like microbes isolated from the 9 samples examined 3 (about 33·3 per cent.) were, on the basis of the tests employed, typical B. Coli.

INDOL TEST.

9 Samples.

4 Samples (about 40 per cent.) contained at least 100,000 per c.c.
3 Samples (about 30 „) „ „ 10,000 „
1 Sample (about 10 „) „ „ 1,000 „
2 Samples (about 20 „) „ „ 100 „

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester New (not mature) Half-Acre Beds.

Indol Test.

100,000 ✦
✦ ✦ ✦ ✦ ✦ ✦ ✦ ✦ about 40 per cent.

10,000 ✦ about
30 per cent.

1,000 ✦ ✦ ✦ ✦ ✦ ✦ ✦ ✦ ✦ ✦ about 10 per cent.

100 ✦ about 20 per cent.

B. ENTERITIDIS SPOROGENES TEST.

6 Samples.

4 Samples contained at least 10 per c.c. (+ 1 c.c.)
2 Samples „ „ 1 „ (+ 1 c.c.)

BILE SALT GLUCOSE PEPTONE TEST.

7 Samples.

3 Samples contained at least 100,000 per c.c.
3 Samples „ „ 10,000 „
1 Sample „ „ 1,000 „

NEUTRAL RED BROTH TEST.

6 Samples.

5 Samples contained at least 100,000 per c.c.
1 Sample „ „ 10,000 „

SECTION VI.

EFFLUENTS FROM EXPERIMENTAL PRIMARY BEDS, A, B, & C.

BED A.

TOTAL NUMBER OF BACTERIA PER C.C.

(*a*) Gelatine at 20° C.

9 Samples.

Average Number 3,091,111 per c.c.
Greatest Number 6,600,000 „
Least Number 170,000 „
7 Samples contained at least 1,000,000 per c.c.
2 Samples „ „ 100,000 „

(*b*) Agar at 37° C.

9 Samples.

Average Number 579,333 per c.c.
Greatest Number 1,500,000 „
Least Number 24,000 „
2 Samples contained at least 1,000,000 per c.c.
5 Samples „ „ 100,000 „
2 Samples „ „ 10,000 „

B. COLI TEST.—Number of B. Coli (or closely allied forms) in 1 c.c.

8 Samples.

2 Samples contained at least 100,000 per c.c.
3 Samples „ „ 10,000 „
3 Samples „ „ 1,000 „

With regard to the biological attributes of the B. Coli or coli-like microbes isolated from the samples, 1 microbe of the 8 microbes isolated (about 12·5 per cent.) was found to be, on the basis of the tests employed, typical B. Coli.

INDOL TEST.

9 Samples.

2 Samples contained at least 100,000 per c.c.
4 Samples „ „ 10,000 „
2 Samples „ „ 1,000 „
1 Sample „ „ 100 „

B. Enteritidis Sporogenes Test.

4 Samples.

2 Samples contained at least 100 per c.c. (+·01 c.c.)
2 Samples „ „ 10 „ + ·1 c.c.)

Bile Salt Glucose Peptone Test.

4 Samples.

1 Sample contained at least 10,000 per c.c.
3 Samples „ „ 1,000 „

Lactose Peptone Test.

5 Samples.

1 Sample contained at least 100,000 per c.c.
2 Samples „ „ 10,000 „
2 Samples „ „ 1,000 „

Neutral Red Broth Test.

4 Samples.

All 4 Samples contained at least 10,000 per c.c.

Litmus Milk Modified Test.

4 Samples.

2 Samples contained at least 100,000 per c.c. (+·00001 c.c.)
2 Samples „ „ 10,000 „ (+·0001 c.c.)

Gas Test.

3 Samples.

(*a*) 24 hours at 20° C.
1 Sample +·1 c.c.,—·01 c.c.
2 Samples +·01 c.c.,—·001 c.c.

(*b*) 48 hours at 20° C.
1 Sample +·001 c.c.,—·0001 c.c.
2 Samples +·0001 c.c.,—·00001 c.c.

BED B.

1 Sample examined.

Total Number of Bacteria per c.c.

Gelatine at 20° C.	Agar at 37° C.
5,500	200

B. Coli Test.—Number of B. Coli (or closely allied forms) in 1 c.c.

A coli-like microbe isolated from ·01 c.c. bore little resemblance, on the basis of the tests employed, to typical B. Coli.

Indol Test.

1 Sample contained at least 10 per c.c.

BED C.

3 Samples examined in all.

Total Number of Bacteria per c.c.

(*a*) Gelatine at 20° C.

2 Samples.

1 Sample contained 220,000 per c.c.
1 „ „ 8,100,000 „

(*b*) Agar at 37° C.

3 Samples.

1 Sample contained at least 100,000 per c.c.
2 Samples „ „ 10,000 „

B. Coli Test. Number of B. Coli (or closely allied forms) in 1 c.c.

3 Samples.

1 Sample contained at least 10,000 per c.c.
1 „ „ „ 1,000 „
1 „ „ „ 100 „

With regard to the biological attributes of the B. Coli or coli-like microbes isolated one of the three microbes was, on the basis of the tests employed, typical B. Coli.

Indol Test.

3 Samples.

1 Sample contained at least 10,000 per c.c.
2 Samples „ „ 100 „

SECTION VII.

EFFLUENTS FROM EXPERIMENTAL SECONDARY BED D.

TOTAL NUMBER OF BACTERIA PER C.C.

(*a*) Gelatine at 20° C.

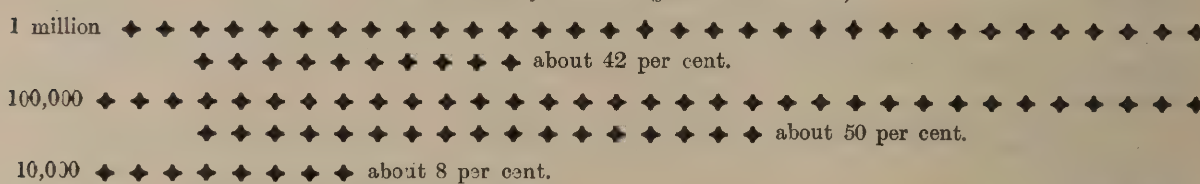
12 Samples.

Average Number	1,135,750 per c.c.				
Greatest Number	4,600,000 ,,				
Least Number	39,000 ,,				
5 Samples (about 42 per cent.)	contained	at least	1,000,000 per c.c.		
6 Samples (about 50 ,,)	,,	,,	100,000 ,,		
1 Sample (about 8 ,,)	,,	,,	10,000 ,,		

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester Experimental Secondary Bed D.

Total number of bacteria (gelatine at 20° C.)



(*b*) Agar at 37° C.

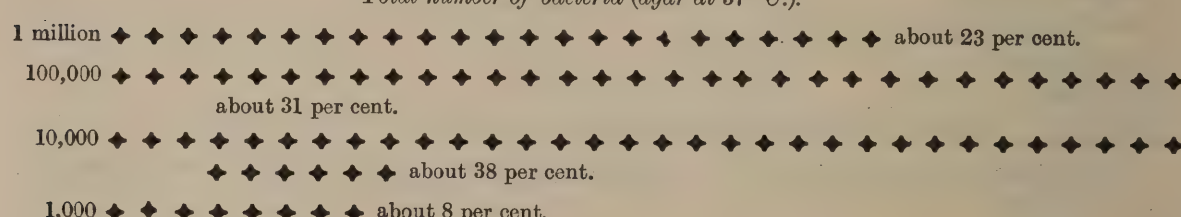
13 Samples.

Average Number	372,969 per c.c.			
Greatest Number	1,300,000 ,,			
Least Number	5,600 ,,			
3 Samples (about 23 per cent.)	contained	at least	1,000,000 per c.c.	
4 Samples (about 31 ,,)	,,	,,	100,000 ,,	
5 Samples (about 38 ,,)	,,	,,	10,000 ,,	
1 Sample (about 8 ,,)	,,	,,	1,000 ,,	

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester Experimental Secondary Bed D.

Total number of bacteria (agar at 37° C.).



B. COLI TEST.—Number of B. Coli (or closely allied forms) in 1 c.c.

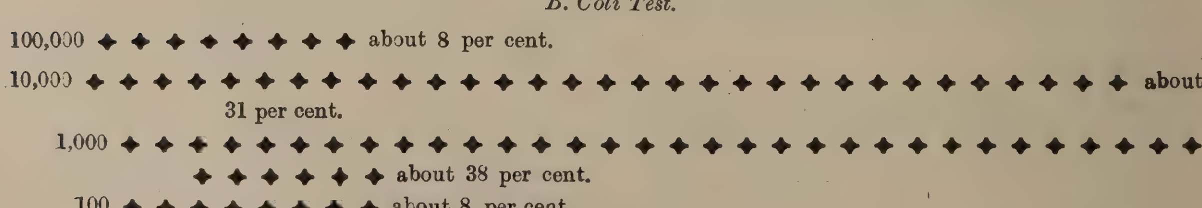
13 Samples.

1 Sample (about 8 per cent.)	contained	at least	100,000 per c.c.
4 Samples (about 31 ,,)	,,	,,	10,000 ,,
5 Samples (about 38 ,,)	,,	,,	1,000 ,,
1 Samples (about 8 ,,)	,,	,,	100 ,,
2 Samples (about 15 ,,)	,,	less than	1,000 ,,

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester Experimental Secondary Bed D.

B. Coli Test.



About 15 per cent. negative result with $\frac{1}{1000}$ c.c.

With regard to the biological attributes of the B. Coli or coli-like microbes isolated from the samples, 2 of the microbes isolated (about 18·1 per cent.) were, judged by the tests employed, typical B. Coli.

INDOL TEST.

13 Samples.

3 Samples (about 23 per cent.)	contained	at least	100,000 per c.c.
3 Samples (about 23 ,,)	,,	,,	10,000 ,,
4 Samples (about 31 ,,)	,,	,,	1,000 ,,
3 Samples (about 23 ,,)	,,	,,	100 ,,

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows:—

Manchester Experimental Secondary Bed D.

Indol Test.

100,000 ◆ about 23 per cent.
10,000 ◆ about 23 per cent.
1,000 ◆
about 31 per cent.
100 ◆ about 23 per cent.

B. Enteritidis Sporogenes Test.

5 Samples.

1 Sample contained at least 100 per c.c. (+ ·01 c.c.)
3 Samples „ „ 10 „ (+ ·1 c.c.)
1 Sample „ „ 1 „ (+ 1 c.c.)

Bile Salt Glucose Peptone Test.

5 Samples.

1 Sample contained at least 100,000 per c.c.
3 Samples „ „ 1,000 „
1 Sample „ less than 1,000 per c.c. (negative result with $\frac{1}{1000}$ c.c.)

Lactose Peptone Test.

8 Samples.

2 Samples contained at least 100,000 per c.c.
4 Samples „ „ 10,000 „
1 Sample „ „ 1,000 „
1 Sample „ less than 1,000 per c.c. (negative result with $\frac{1}{1000}$ c.c.)

Neutral Red Broth Test.

5 Samples.

1 Sample contained at least 100,000 per c.c.
4 Samples „ „ 10,000 „

Litmus Milk Modified Test.

5 Samples.

All 5 samples contained at least 10,000 per c.c. (+ ·0001 c.c.)

Gas Test.

4 Samples.

(*a*) 24 hours at 20° C.

2 Samples + ·1 c.c., − ·01 c.c.
2 Samples + ·01 c.c., − ·001 c.c.

(*b*) 48 hours at 20° C.

1 Sample + ·01 c.c., − ·001 c.c.
2 Samples + ·001 c.c., − ·0001 c.c.
1 Sample + ·0001 c.c., − ·00001 c.c.

SECTION VIII.

EFFLUENTS FROM THE STODDART FILTER.

Total Number of Bacteria per c.c.

(*a*) Gelatine at 20° C

5 Samples.

4 Samples contained at least 1,000,000 per c.c.
1 Sample „ „ 100,000 „

(*b*) Agar at 37° C.

5 Samples.

2 Samples contained at least 1,000,000 per c.c.
2 Samples „ „ 100,000 „
1 Sample „ „ 10,000 „

B. Coli Test. Number of B. Coli (or closely allied forms) in 1 c.c.

6 Samples.

2 Samples contained at least 100,000 per c.c.
2 Samples „ „ 10,000 „
2 Samples „ „ 1,000 „

With regard to the biological attributes of the B. Coli or coli-like microbes isolated from the samples, none of the 5 microbes isolated were, judged by the tests employed, identical with typical B. Coli.

Indol Test.

6 Samples.

3 Samples contained at least 10,000 per c.c.
2 Samples „ „ 1,000 „
1 Sample „ „ 100 „

B. Enteritidis Sporogenes Test.

5 Samples.

2 Samples contained at least 100 per c.c. (+ ·01 c.c.)
3 „ „ „ 10 „ (+ ·1 c.c.)

Bile Salt Glucose Peptone Test.

3 Samples.

1 Sample contained at least 100,000 per c.c.
1 Sample „ „ 10,000 „
1 Sample „ „ 100 „

Neutral Red Broth Test.

5 Samples.

3 Samples contained at least 100,000 per c.c.
2 Samples „ „ 10,000 „

Litmus Milk Modified Test.

3 Samples.

1 Sample contained at least 100,000 per c.c. (+ ·00001 c.c.)
2 Samples „ „ 10,000 „ (+ ·0001 c.c.)

Gas Test.

2 Samples.

(*a*) 24 hours at 20° C.

1 Sample + ·1 c.c., — ·01 c.c.
1 Sample + ·01 c.c., — ·001 c.c.

(*b*) 48 hours at 20° C.

Both Samples + ·001 c.c., — ·0001 c.c.

SECTION IX.

ROSCOE COKE AND CINDER FILTERS.

Dunbar Filter.

Filtered Effluents.

New Primary Beds.

The samples obtained from the above several sources were in each instance too few in number for any summary to be appended here.

SECTION X.

EFFLUENTS FROM STORM BEDS.

[N.B.—In time of storm the whole of the storm sewage (apart from that passing through the septic tanks) passed through settling tanks, and the "storm beds" deal with the effluent from these tanks.]

The following summary is inclusive of all the results of the bacteriological examination of samples derived from the storm beds :—

Total Number of Bacteria per c.c.

(*a*) Gelatine at 20° C.

11 Samples.

Average number, 3,717,272 per c.c.
Greatest number, 10,000,000 „
Least number - 390,000 „
1 Sample (about 9 per cent.) contained at least 10,000,000 per c.c.
8 Samples (about 73 „) „ „ 1,000,000 „
2 „ (about 18 „) „ „ 100,000 „

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester Storm Beds.

Total number of bacteria (gelatine at 20° C.)

10,000,000 ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ about 9 per cent.

1,000,000 ◆
◆ ◆
◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ about 73 per cent.

100,000 ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ about 18 per cent.

(*b*) Agar at 37° C.

13 Samples.

Average Number 694,000 per c.c.
Greatest Number 2,600,000 „
Least Number 10,000 „
4 Samples (about 31 per cent.) contained at least 1,000,000 per c.c.
4 Samples (about 31 „) „ „ 100,000 „
5 Samples (about 38 „) „ „ 10,000 „

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester Storm Beds.

Total Number of bacteria (agar at 37° C.)

1 million ◆
about 31 per cent.

100,000 ◆
about 31 per cent.

10,000 ◆
◆ ◆ ◆ ◆ ◆ ◆ about 38 per cent.

B. Coli Test. Number of B. Coli (or closely allied forms) in 1 c.c.

13 Samples.

1 Sample	(about 8 per cent.)	contained at least	100,000	per c.c.
4 Samples	(about 30 „)	„ „	10,000	„
6 Samples	(about 46 „)	„ „	1,000	„
1 Sample	(about 8 „)	„ „	100	„
1 Sample	(about 8 „)	„ less than	100	„

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester Storm Beds.

B. Coli test.

100,000 ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ about 8 per cent.

10,000 ◆ about
30 per cent.

1,000 ◆
◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ about 46 per cent.

100 ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ about 8 per cent.

About 8 per cent. negative result with $\frac{1}{100}$ c.c.

With regard to the biological attributes of the B. Coli or coli-like microbes isolated from the samples, 3 out of 12 microbes isolated (25 per cent.) were, on the basis of the tests employed, typical B. Coli.

Indol Test.

13 Samples.

2 Samples	(about 15 per cent.)	contained at least	100,000	per c. c.
4 Samples	(about 31 „)	„ „	10,000	„
6 Samples	(about 46 „)	„ „	1,000	„
1 Sample	(about 8 „)	„ „	100	„

These results may be illustrated by a diagram (each dot represents one per cent. of the samples) as follows :—

Manchester Storm Beds.

Indol Test.

100,000 ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ about 15 per cent.

10,000 ◆ about
31 per cent.

1,000 ◆
◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ about 46 per cent.

100 ◆ ◆ ◆ ◆ ◆ ◆ ◆ ◆ about 8 per cent.

B. Enteritidis Sporogenes Test.

9 Samples.

6 Samples contained at least 10 per c.c. (+·1 c.c.)
3 Samples „ „ 1 „ (+1 c.c.)

Bile Salt Glucose Peptone Test.

3 Samples.

All 3 samples contained at least 10,000 per c.c.

Lactose Peptone Test.

5 Samples.

2 Samples contained at least 100,000 per c.c.
2 Samples „ „ 10,000 „
1 Sample „ „ 1,000 „

Neutral Red Broth Test.

9 Samples.

4 Samples contained at least 100,000 per c.c.
4 Samples „ „ 10,000 „
1 Sample „ „ 1,000 „

It will be noted that on the majority of the dates on which samples of the effluent from the Storm Beds were taken the rainfall in Manchester was not excessive. A table is appended showing the actual rainfall on the various dates.

FILTRATE FROM STORM BEDS.

Time.	Day.	Month.	Year.	No. of Fillings per 24 hours.	Remarks.
5.30 p.m.	30	9	1902.	1	Dry
5. 0 ,,	7	10		1	,,
	28	10		1	,, Beds not been long in use.
5. 0 ,,	17	11		1	,,
5. 0 ,,	21	11		1	,,
3.35 ,,	2	12		1	·875″ Rain. Worked continuously for ½ hour.
2.30 ,,	8	12		1	Dry.
3.25 ,,	29	1	1903.	1	,,
11.17 ,,	30	1		1	,,
3.15 ,,	3	2		1	Slight Rain.
4.30 ,,	3	9	1904.	2	·47″ Rain. Worked continuously for 3 hours.
	8	9		1	Slight Rain.
3.30 ,,	14	9		1	Dry.
2.30 ,,	20	9		1	,,
	27	9		1	,,
	26	10		1	,,
2.15 ,,	15	11		2	Slight Rain.
3.30 ,,	23	11		2	·135″ ,,
	29	11		2	Slight Rain.
3.30 ,,					

TABLE illustrating the Cultural Characters of B. coli and Coli-like Microbes isolated in pure culture from samples obtained from Manchester.
(Figures enclosed in brackets [ ] are percentage figures based on a total of less than 10 samples.)

SOURCE.	Producing indol and clot.	Producing neither indol nor clot.	Producing clot but no indol.	Producing indol but no clot.	Failing to produce indol.	Failing to produce clot.
Raw and settled sewage	*26·6 per cent.* 12 out of 45.	*33·3 per cent.* 15 out of 45.	*35·5 per cent.* 16 out of 45.	*4·4 per cent.* 2 out of 45.	*68·8 per cent.* 31 out of 45.	*37·7 per cent.* 17 out of 45.
Septic tank liquor	*20·3 per cent.* 11 out of 54.	*40·9 per cent.* 22 out of 54.	*33·3 per cent.* 18 out of 54.	*5·5 per cent.* 3 out of 54.	*74 per cent.* 40 out of 54.	*46·2 per cent.* 25 out of 54.
Chemically precipitated sewage	*33·3 per cent.* 8 out of 24.	*16·6 per cent.* 4 out of 24.	*37·5 per cent.* 9 out of 24.	*12·2 per cent.* 3 out of 24.	*54·1 per cent.* 13 out of 24.	*25 per cent.* 7 out of 24.
Effluent from mature half-acre primary contact beds	*13·8 per cent.* 9 out of 65.	*38·4 per cent.* 25 out of 65.	*44·6 per cent.* 29 out of 65.	*3 per cent.* 2 out of 65.	*83 per cent.* 54 out of 65.	*41·5 per cent.* 27 out of 65.
Effluents from new (not mature) half-acre primary contact beds	[*33·3 per cent.*] 3 out of 9.	[*11·1 per cent.*] 1 out of 9.	[*55·5 per cent.*] 5 out of 9.	—	[*66·6 per cent.*] 6 out of 9.	[*11 per cent.*] 1 out of 9.
Experimental primary bed A	[*12·5 per cent.*] 1 out of 8.	[*37·5 per cent.*] 3 out of 8.	[*50 per cent.*] 4 out of 8.	—	[*87·5 per cent.*] 7 out of 8.	[*37·5 per cent.*] 3 out of 8.
" " beds B and C	[*25 per cent.*] 1 out of 4.	[*50 per cent.*] 2 out of 4.	[*25 per cent.*] 1 out of 4.	—	*75 per cent.* 3 out of 4.	*50 per cent.* 2 out of 4.
" secondary bed D	[*18·1 per cent.*] 2 out of 11.	*54·5 per cent.* 6 out of 11.	*9 per cent.* 1 out of 11.	*18·1 per cent.* 2 out of 11.	*63·6 per cent.* 7 out of 11.	*72·7 per cent.* 8 out of 11.
Effluents from Stoddart filters	—	[*40 per cent.*] 2 out of 5.	[*60 per cent.*] 3 out of 5.	—	[*100 per cent.*] 5 out of 5.	[*40 per cent.*] 2 out of 5.
Effluents from Roscoe filters and filtered effluents	[*14·2 per cent.*] 1 out of 7.	[*71·4 per cent.*] 5 out of 7.	[*14·2 per cent.*] 1 out of 7.	—	[*85·7 per cent.*] 6 out of 7.	[*71·4 per cent.*] 5 out of 7.
Effluents from storm beds	*25 per cent.* 3 out of 12.*	*25 per cent.* 3 out of 12.	*25 per cent.* 3 out of 12.	*16·6 per cent.* 2 out of 12.	*50 per cent.* 6 out of 12.	*41·6 per cent.* 5 out of 12.
Total sewage septic tank liquor and chemically precipitated sewage	*25·2 per cent.* 31 out of 123.	*33·3 per cent.* 41 out of 123.	*34·9 per cent.* 43 out of 123.	*6·5 per cent.* 8 out of 123.	*68·2 per cent.* 84 out of 123.	*39·8 per cent.* 49 out of 123.
Total inclusive of all effluents	*16·5 per cent.* 20 out of 121.*	*38·8 per cent.* 47 out of 121.	*38·8 per cent.* 47 out of 121.	*4·9 per cent.* 6 out of 121.	*77·6 per cent.* 94 out of 121.	*43·8 per cent.* 53 out of 121.
Total inclusive of all microbes isolated from the samples	*20·9 per cent.* 51 out of 244.	*36·0 per cent.* 88 out of 244.	*36·8 per cent.* 90 out of 244.	*5·7 per cent.* 14 out of 244.	*72·9 per cent.* 178 out of 244.	*41·8 per cent.* 102 out of 244.

* One microbe (not included) produced indol and clot, but rendered milk alkaline.

GENERAL REMARKS.

Comparison of diagrams M1 to M9 (both inclusive) serve to show that the effluents from the mature primary contact half-acre beds were considerably purer, bacteriologically, on a percentage basis of comparison, than the Manchester sewage, septic tank liquor, or chemically precipitated sewage.

With regard to the B. coli * test, the effluent from the mature primary contact half-acre beds showed improvement when compared with the Manchester sewage. Improvement in these effluents is likewise to be noted when their behaviour is compared with that of the Manchester sewage towards the lactose peptone and neutral red broth tests.

Judged by the B. enteritidis sporogenes test, the septic tank liquor showed some improvement on the Manchester sewage, while the effluents from the mature primary contact half-acre beds were about ten times purer than the sewage.

In relation to the bacteriological results, it is of interest to extract the following information from the evidence given by Mr. Fowler before the Commission :—

"Manchester sewage is not to be thought of as a strong sewage. The flow per head of population averaging in dry weather 40 to 50 gallons, the sewage may be considered as a dilute solution of domestic sewage in trade effluents and subsoil water. The trade effluents include among others refuse from dyeing and bleaching works, oil and grease refining, candle-making, soap, size, &c., works, india-rubber factories, galvanising and brass-finishing factories, chemical manufacture, *e.g.*, sulphate of ammonia works, tar distilling, aniline works, alkali works. This would account for the presence at times in the sewage of acid, tar, iron, pickle, phenols, and compounds of naphthalene, and also sulphocyanates. The sewage has been found to be practically always alkaline ; the sludge tends, without the addition to it of lime, to become acid owing to the decomposition of fats. The raw sewage contains a considerable proportion of cotton waste and fibrous material, which is eliminated by preliminary screening in order to obviate blocking of the ejectors with waste."

With regard to septic tank liquor, the majority of the samples were derived from open septic tanks, while a very few were taken from the Cameron closed septic tank. The results have for convenience been incorporated together.

The chemically precipitated sewage presents (regarded from the bacteriological view point) some features of interest. The precipitants used are lime and copperas, and the precipitation effluent is found as a rule to be faintly alkaline.

* The percentage number of *typical* B. coli, on the basis of the tests employed, was exceptionally low in the Manchester samples.

It will be noted that the chemically precipitated sewage contained on the whole a greater number of bacteria (both growing on gelatine at 20° C. and on agar at 37° C.) than did the raw sewage. Judged, however, by the number of B. coli or coli-like microbes present per cubic centimetre and by the bile salt glucose peptone test, the chemically precipitated showed some improvement on the raw sewage.

The effluents from the new (not mature) primary contact half-acre beds showed a high total bacterial content per cubic centimetre ; but such samples as were examined by the B. enteritidis sporogenes test showed improvement in comparison with the sewage. As regards the B. coli and indol tests, the results were not very satisfactory from the bacteriological point of view. The samples obtained from the Experimental Primary Bed A were not many in number ; but those examined showed, in comparison with the sewage, improvement as regards total bacterial content, and also judged by the B. coli and indol tests.

The effluents examined, which were derived from the Experimental Secondary Bed D were purer bacteriologically than the effluent from Primary Bed A. The samples examined of the effluents from the Stoddart filter, the Roscoe coke and cinder filters, and the Dunbar filter were too few in number to allow of any useful conclusions being drawn. With regard to the effluent from the Storm Beds, it should be noted that the beds dealt during 1902–1903 in dry weather with chemically precipitated sewage, while during 1904 the beds were in dry weather dealing with settled sewage. In time of storm the whole of the storm sewage (apart from that passing through the septic tanks) is passed through settling tanks, and the storm beds deal with the effluent from these tanks.

The effluents from the Storm Beds showed, generally speaking, as regards all the tests employed, a considerable degree of percentage purification as compared with the sewage.

Dealing with the Manchester results as a whole, it cannot be said that the results were good bacteriologically, and seemed to be less satisfactory than has been observed in some other places, more particularly those where percolating filters are used instead of contact beds.

It must be remembered, however, that the effluents are discharged into the Manchester Ship Canal, and hence the chemical results are here of special importance.

But the results of the bacteriological examination of these numerous samples lend support to the opinion previously advanced, namely, that the effluents from contact beds are not in a fit state bacteriologically to be discharged into drinking water streams.

I desire to acknowledge the valuable assistance rendered by Miss Chick, Miss Power, and Miss Hartley in connexion with the bacteriological examination of the Manchester samples. Most of the analytical work was carried out by Miss Chick, and Miss Power has been kind enough to tabulate the results. I am greatly indebted to Mr. Fowler and his colleagues for sending me the samples and supplying me with much valuable information.

Diagram M.I Shewing the results of the Bacteriological Examination of Manchester Sewage

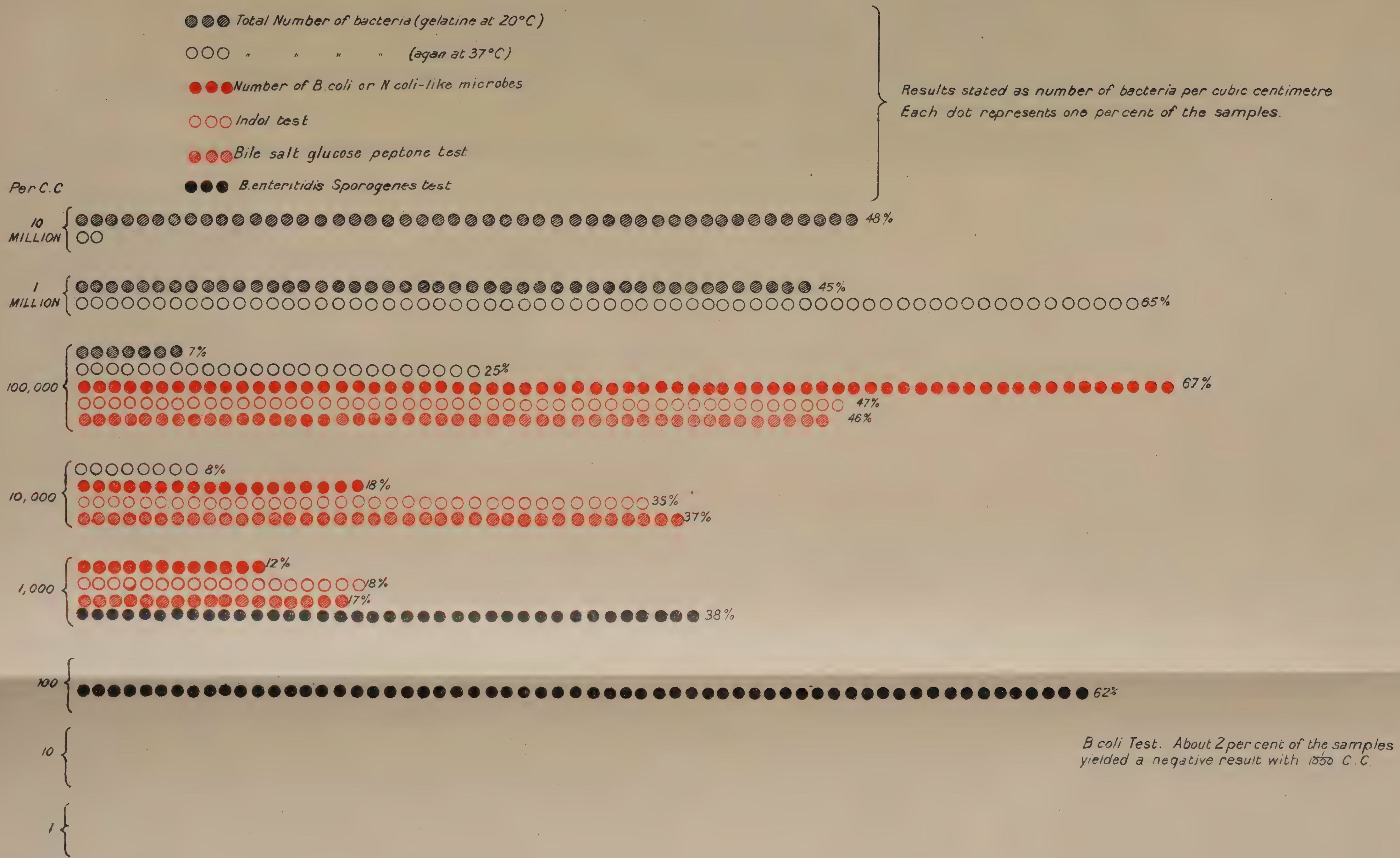


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Diagram M2 Shewing the Results of the Bacteriological Examination of Manchester Septic Tank Liquid

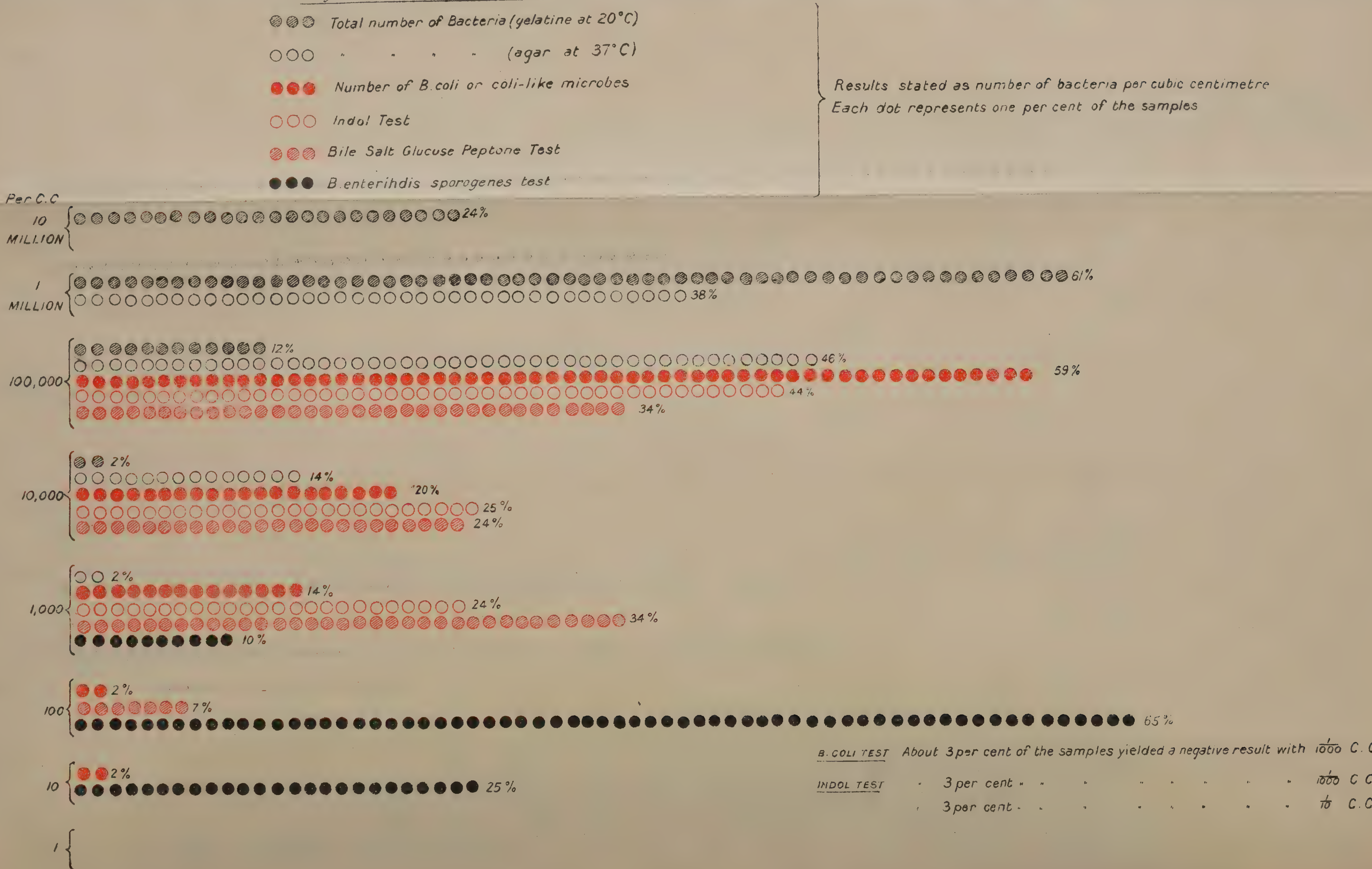

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Diagram M3. Shewing the Results of the Bacteriological Examination of Manchester Sewage Chemically Precipitated.

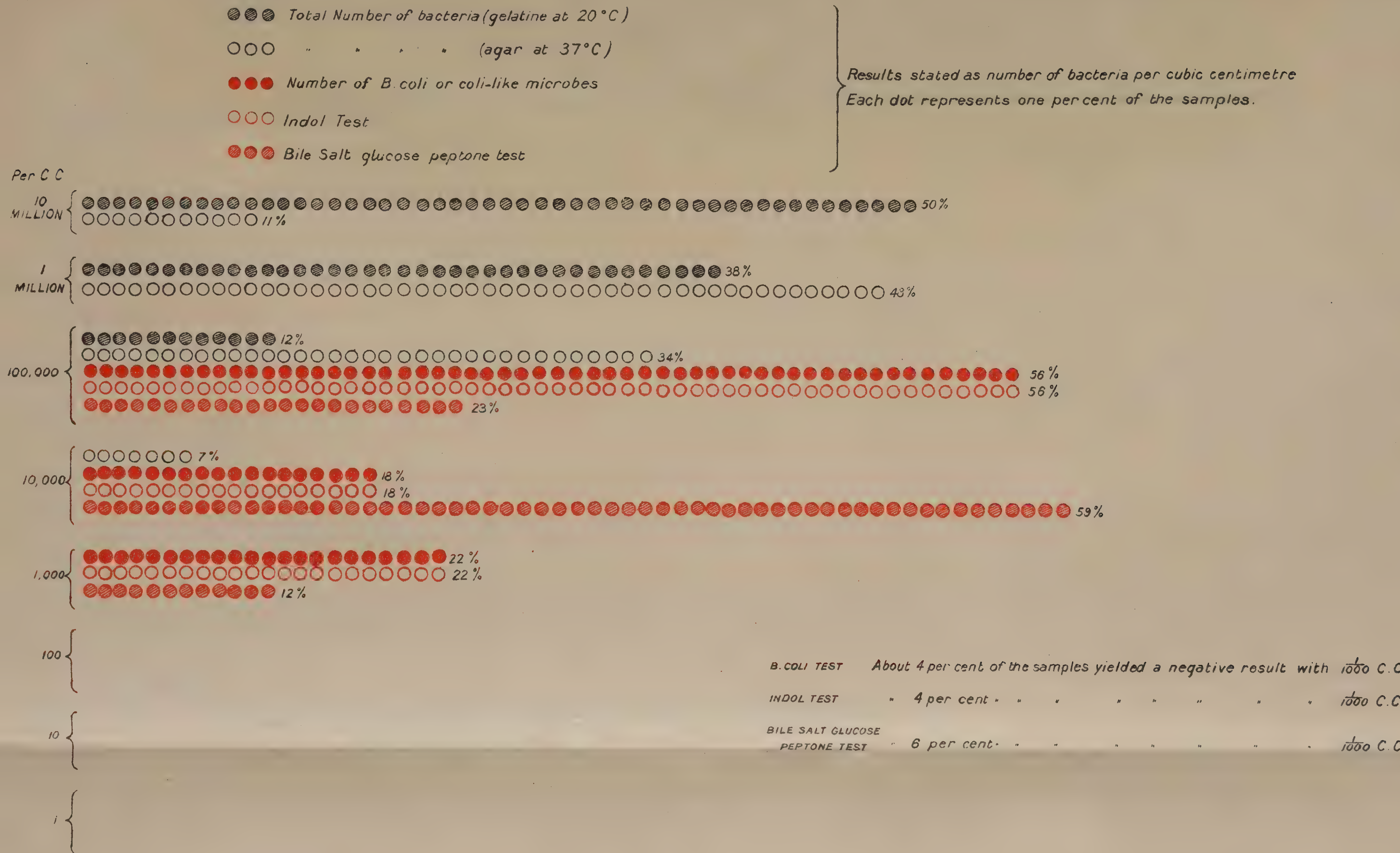

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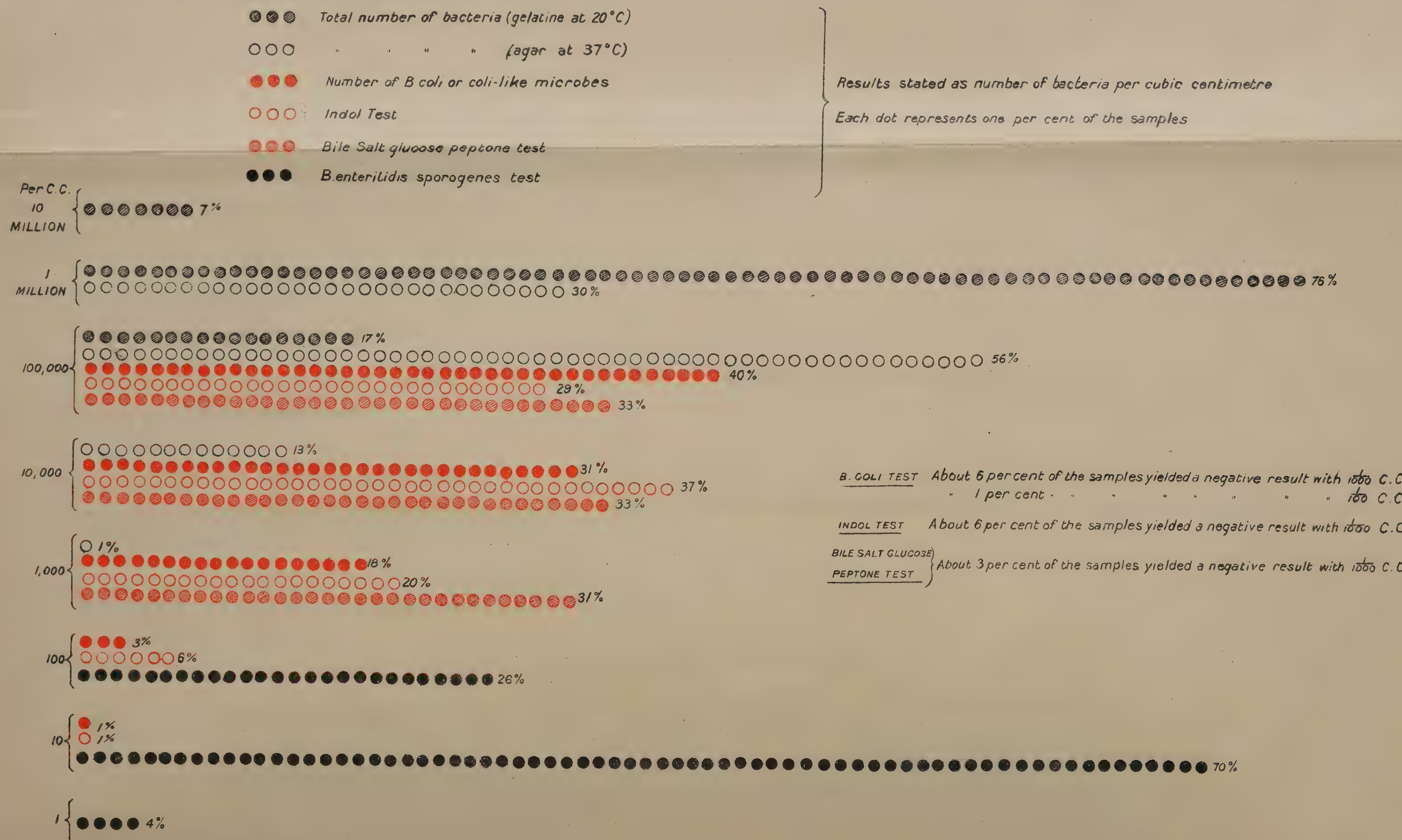
Diagram M.4 Shewing the Results of the Bacteriological Examination of the Effluents from Mature Primary Contact Half Acre Beds at Manchester



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Total Number of Bacteria (Gelatine at 20°C) Comparison of the results of the Bacteriological Examination of Manchester Sewage, Septic Tank Liquid, Chemically Precipitated Sewage and Effluents from Mature Primary Contact Half Acre Beds.

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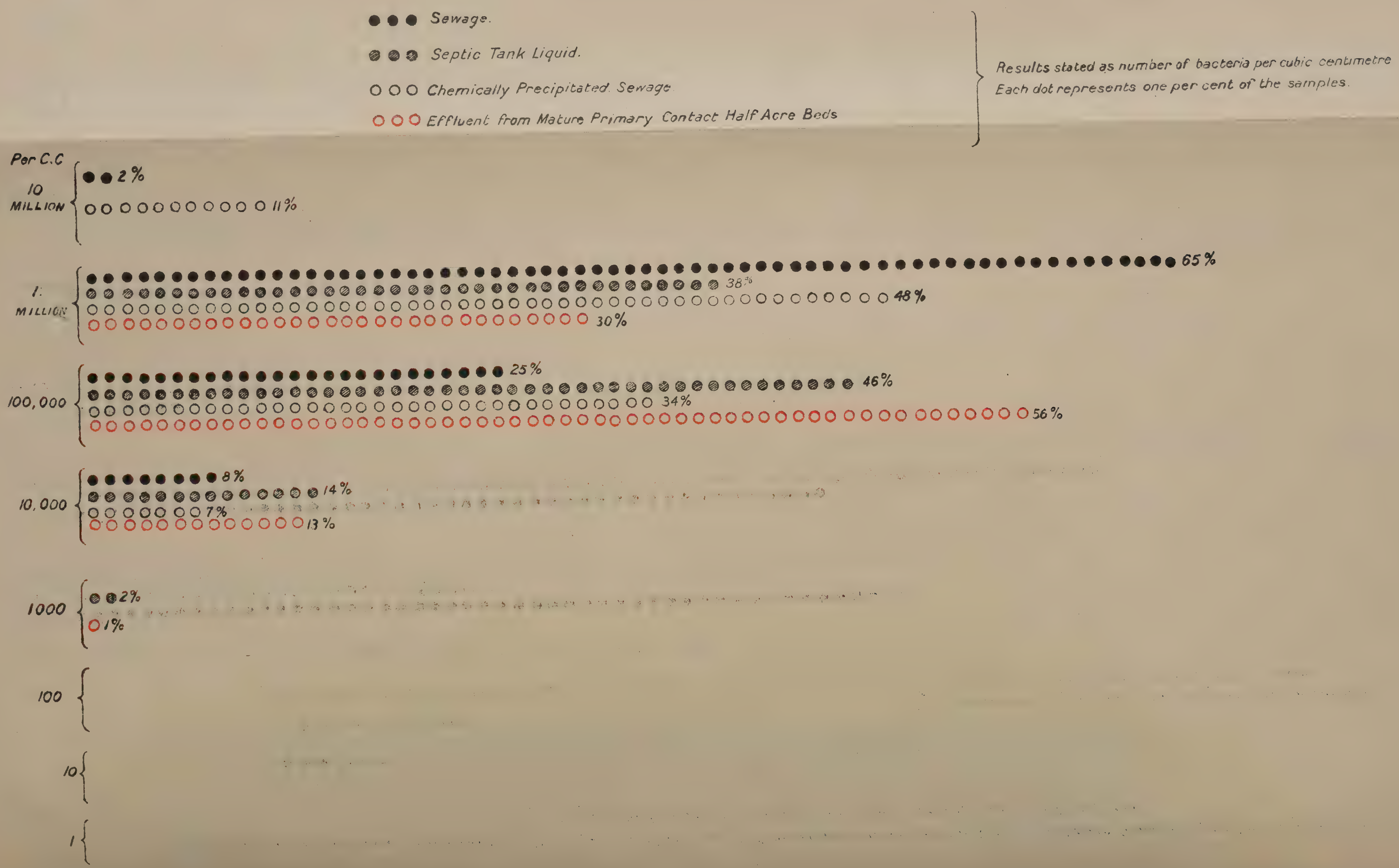
Diagram M. 6.

Total Number of Bacteria (agar at 37°C) Comparison of the Results of the Bacteriological Examination of Manchester Sewage, Septic Tank Liquid, Chemically Precipitated Sewage and Effluents from Mature Primary Contact Half Acre Beds.



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Number of B.Coli or Coli-like Microbes — Comparison of the results of the Bacteriological Examination of Manchester Sewage, Septic Tank Liquid Chemically Precipitated Sewage and Effluents from Mature Primary Contact Half Acre Beds.

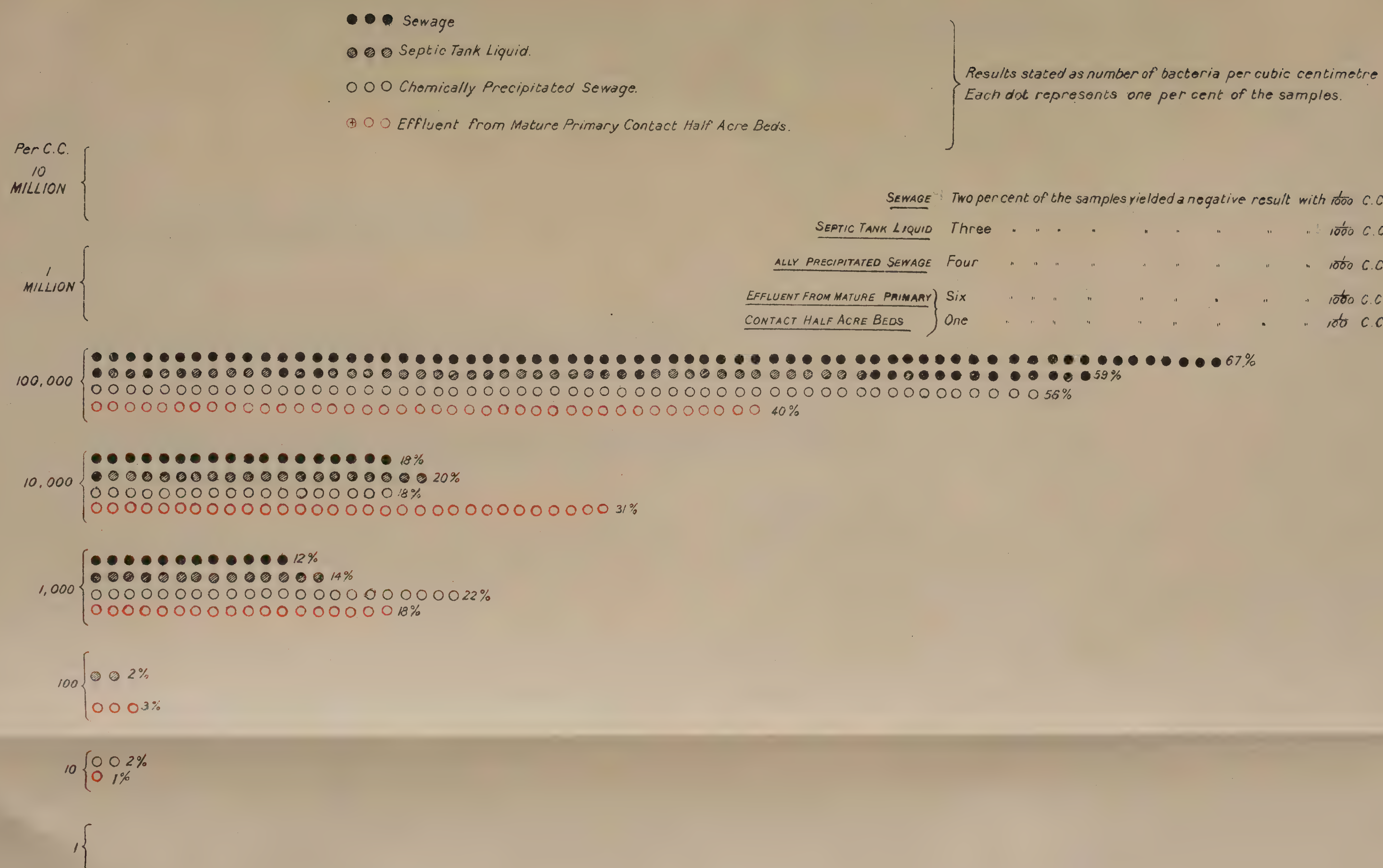

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Diagram M. 8

Indol Test Comparison of the Results of the Bacterilogical Examination of Manchester Sewage, Septic Tank Liquid, Chemically Precipitated Sewage and Effluents from Mature Primary Contact Half Acre Beds

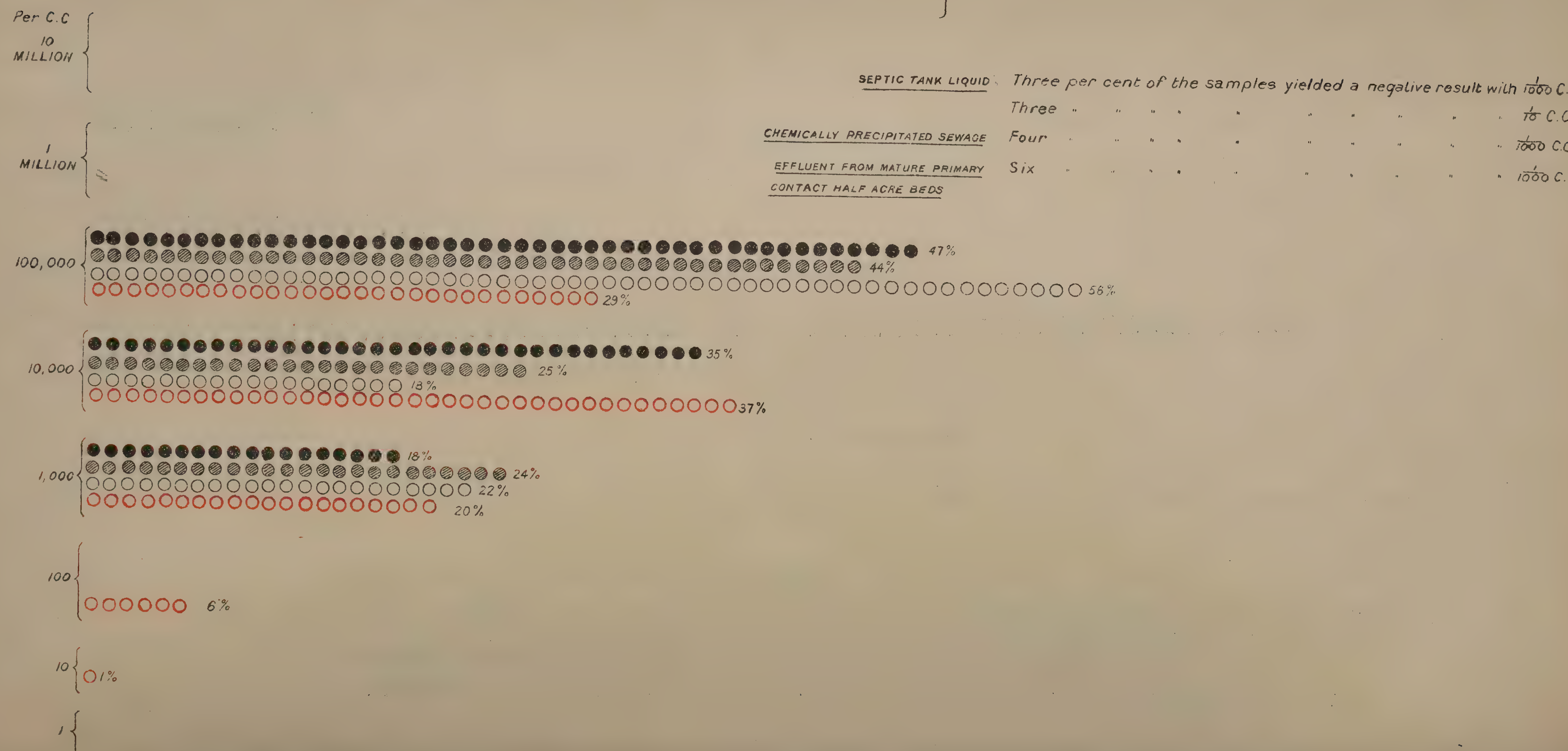
●●● Sewage

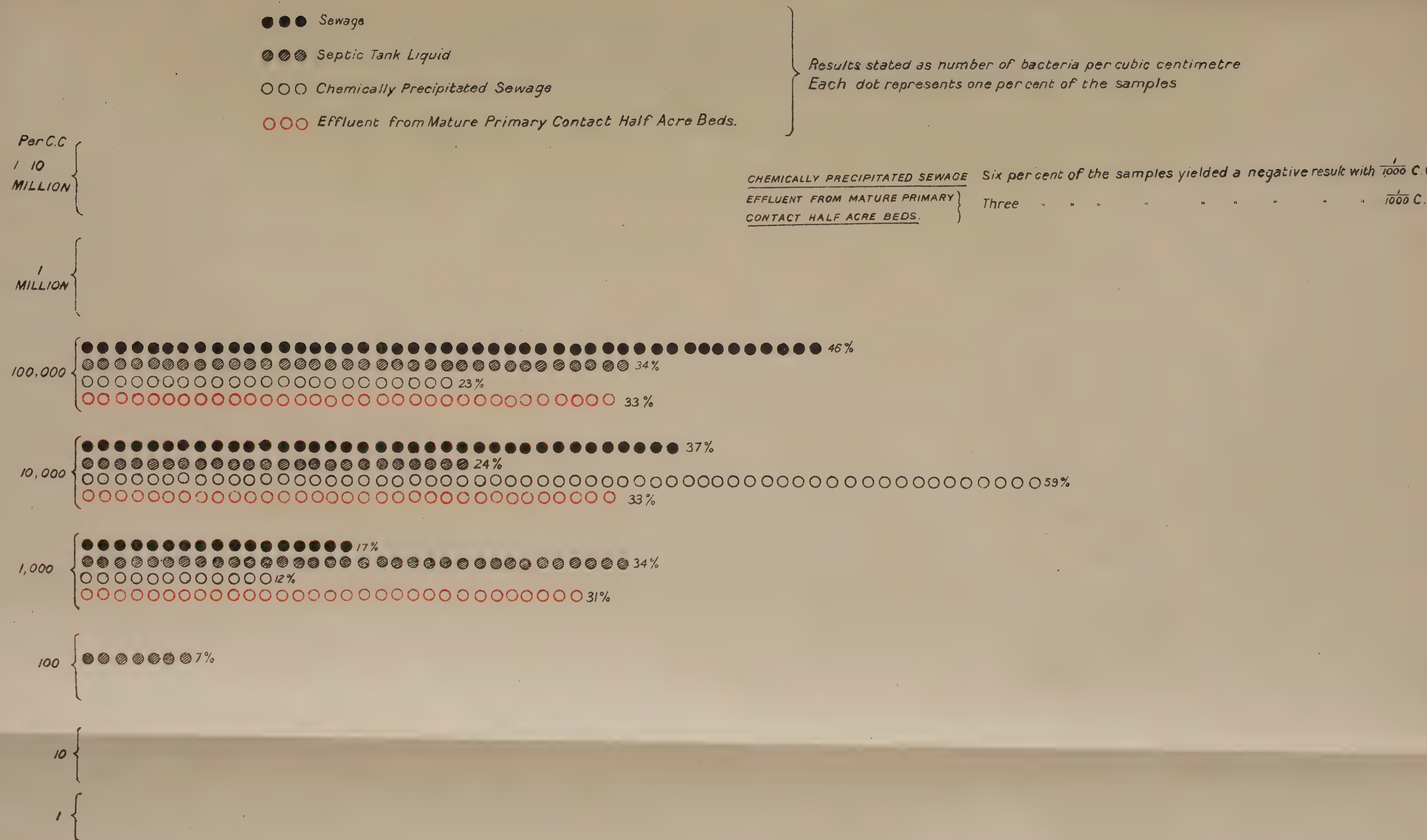
◍◍◍ Septic Tank Liquor

○○○ Chemically Precipitated Sewage.

○○○ Effluent from Mature Primary Contact Half Acre Beds.

Results stated as number of bacteria per cubic centimetre
Each dot represents one per cent of the samples





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ADDENDUM.

TABLE showing Rainfall in Manchester in connection with the time at which samples were taken for the Royal Commission on Sewage Disposal.

ROYAL COMMISSION—BACTERIOLOGICAL EXAMINATION—RAW SEWAGE.

Time.	Day.	Month.	Year.	Total Number of Bacteria in 1 c.c. of Raw Sewage.	Rainfall.
5.15 p.m.	10	3	1902.	8,600,000	Dry weather for 2 previous days.
3.15 "	11	3		12,000,000	" " 3 " "
9.10 a.m.	14	3		1,100,000	·145″ noon 12th—noon 14th.
10.35 "	19	3		1,000,000	Slight rain from 14th.
4.30 p.m.	25	4		500,000	·18″ 22nd, ·005″ 23rd, ·075″ 24th, ·01″ 25th.
9.45 a.m.	29	4		540,000	No rain since 25th.
9.30 "	1	5		200,000	·26″ 28th, March—April 1st (Easter).
4.30 p.m.	2	5		7,000,000	No rain 2nd April.
4. 0 "	6	5		3,300,000	·335″ 4th, ·52″ 5th, ·145″ 6th and 7th.
4. 0 "	9	5		1,500,000	No rain since 7th.
4. 0 "	13	5		4,800,000	No rain since 7th. 13th and 14th ·145″.
3.15 "	19	5		29,000,000	Dry 18th and 19th.
4.45 "	22	5		9,300,000	·18″ noon 21st—noon 22nd.
3.15 "	23	—		14,000,000	Trace noon 22nd—noon 23rd, ·075″ to noon 24th.
3.30 "	30	—		9,400,000	·125″ 28th and 29th, ·185″ 29th and 30th, ·12″ 30th and 31st.
3.30 "	4	6		17,000,000	Dry.
4.30 "	5	6		18,000,000	·030″ 4th and 5th, ·105″ 5th and 6th.
3.15 "	9	6		18,000,000	·115″ 8th and 9th.
12.30 "	11	6		4,600,000	Dry.
4.45 "	12	6		7,100,000	·04″ 11th and 12th.
4. 0 "	16	6		19,000,000	Dry.
4.15 "	17	6		10,000,000	·115″ 16th and 17th.
4.50 "	23	7		4,600,000	·23″ 22nd and 23rd, ·015″ 23rd and 24th.
4.30 "	19	9		32,000,000	No rain.
12. 0 noon	23	9		10,000,000	·15″ 22nd and 23rd, ·08″ 23rd and 24th.
5. 0 p.m.	26	9		17,000,000	No rain.
5.30 "	30	9		19,000,000	No rain.

ADDENDUM—*continued.*

RAW SEWAGE.

Time.	Day.	Month.	Year.	Gelatine. No. per c.c. 20° C.	Rainfall.
4.30 p.m.	3	10	1902	8,300,000	·03″ 2nd and 3rd. ·005″ 3rd and 4th.
5. 0 „	7			18,000,000	No rain.
5. 0 „	10			18,000,000	·75″ 9th and 10th. ·12″ 10th and 11th.
—	14			No record	1·03″ 13th and 14th.
3.10 p.m.	17	10		13,000,000	·20″ 15th and 16th. ·425″ 16th and 17th. ·18″ 17th and 18th.
5. 0 „	21			11,000,000	·20″ 19th and 20th. ·02″ 20th and 21st. ·21″ 21st and 22nd.
3. 0 „	23			4,600,000	No rain.
4.15 „	12	11		9,000,000	·18″ 11th and 12th. No rain 12th and 13th.
5. 0 „	14			12,000,000	·035″ 13th and 14th. ·11″ 14th and 15th.
4.45 „	19			19,000,000	No rain for 4 previous days.
4.30 „	21			1,300,000	Do. 6 „ „
4. 0 „	24			No records	
11. 0 a.m.	26				
12.0 noon	28				
—	2	12		1,500,000	·875″ 1st and 2nd. ·04″ 2nd and 3rd.
3.45 p.m.	4			4,200,000	No rain.
2.30 „	8			No records	Do.
4.30 „	12			2,100,000	No rain for 8 previous days.
3. 0 „	29	1	1903	11,000,000	·54″ 27th and 28th. ·10″ 28th and 29th. Nil 29th and 30th.
4.45 „	30			10,000,000	No rain.
3.40 „	5	2		No record	
4.35 „	19			Do.	

REPORT to the Commission on the Number and Biological Characters of B. coli in Normal Human Fæces,* in Sewage, and in Sewage Effluents.

By Dr. A. C. Houston.

CONTENTS.

[This Report was written early in 1905. In July 1905 my appointment as Director of Water Examinations, Metropolitan Water Board, enabled me to collect together a great deal of information as regards the number and biological attributes of B. coli in river water, before and after filtration. These results, together with certain modifications of method, have been described in my Monthly and Annual Reports to the Metropolitan Water Board.—A. C. H.]

January 2nd, 1905.

The *B. coli* test is being used to an increasingly great extent to determine the purity or otherwise of drinking water and various liquid and solid foods.

Notwithstanding the large amount of work which has been carried out on the subject, knowledge is still incomplete as regards correlation of the number and biological attributes of B. coli in human fæces, in sewage, and in sewage effluents. Thus, although much work has been published on the biological characters of B. coli, and although the numerical abundance of the B. coli group in excremental matters has recently attracted considerable attention, the importance of correlating these two factors on a broad basis of observation does not seem to have been sufficiently recognised.

Again, a great deal has been written on the subject of what constitutes *typical* B. coli, but determinations in this sense would be of greater value had they followed instead of preceding systematic detailed investigation of the correlations to which I refer.†

It is, for example, undesirable to condemn waters because they contain a particular microbe believed to be of excremental origin without comprehensive knowledge of both the number and attributes of the same microbe in excrement *per se*. It is difficult also to see the full justice of bacteriological standards as regards waters in the absence, comparatively speaking, of quantitative and qualitative bacteriological standards in respect of human fæces and sewage.

* The results as regards the B. coli of normal human fæces are taken from my report to the Local Government Board on the bacteriology of the normal stools of healthy persons. (Report of the Medical Officer, Local Government Board, 1902-3. Appendix B, No. 5.)

† At all events, from the point of view of the Commissioners, it is essential to base any conceptions of this kind on comprehensive knowledge of the biological characters of B. coli actually isolated from definite amounts of fæces, sewages, and sewage effluents.

In practice, the material polluting waters is commonly sewage; but, strictly speaking, the contaminating substances that are most undesirable in water are constituents of sewage—namely, human fæces and urine.* Domestic sewage indeed is a variable mixture of human fæces, urine, paper, grit, refuse of various kinds, and soapy dirty water diluted with pure drinking water and other innocuous substances. It is necessary, then, to study the bacteriology not only of sewage but of human excrement in relation to the bacterial contamination of drinking water and of food materials.

At the present time the position as regards the B. coli test of the bacteriologist who is an epidemiologist is as follows:

On the one hand it is admitted that :—

The bacteriologist cannot measure the *actual* "disease value" of a given pollution—say of water.

The excrement of the lower animals may contain B. coli in abundance.

B. coli even of human origin may be, relatively speaking, quite harmless to human beings.

Under peculiarly favourable conditions B. coli may persist for a long time and may even multiply outside the animal body.

The B. coli test is an *indirect* way of measuring the *degree of probability* of presence in a substance of specific bacteria in addition to the comparatively harmless B. coli.

Even in cases where, from the results of the B. coli test, there is every reason to infer the occasional presence in water of specific bacteria, the danger to be apprehended cannot be gauged because the morbific *effect* of the virus of disease is controlled by laws concerning which little is known. †

Observed facts (topographical and epidemiological) appear to show that the results of the B. coli test may greatly over-estimate in some cases and under-estimate in others the degree of potential danger to health arising from sewage pollution of water.

On the other hand, it is claimed that :—

The bacteriologist can always measure the "excremental value," and in a sense can usually estimate the *potential* "disease value," of a given pollution of (say) water, subject to certain qualifications and under the conditions likely to occur in practice.

We have yet to learn that all the microbial elements of the intestinal evacuations of the lower animals are harmless to man.

B. coli artificially added to chemically pure water tends to lose its viability somewhat quickly.

It is usually better to measure potential danger to health due to sewage pollution of water by definite although indirect means than by indefinite expressions of opinion.

B. coli is absent from a large volume of a water which is obtained from a source far removed from all chance of objectionable pollution, and it is present in human fæces and in sewage in enormous numbers.

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* It has been stated that about 20—25 per cent. of enteric fever patients suffer from typhoid bacilluria. In the presence of this complication, the urine may contain for weeks or months the typhoid bacillus in enormous numbers.

† It is, for example, difficult to believe that it is solely the *number* of living typhoid bacilli that govern the occurrence, extent, and severity of an epidemic of enteric fever. Probably it is largely a question of *virulence* as well as of number. Possibly also there are factors beyond our ken which, directly or indirectly, influence the morbific effect of a given dose of specific pollution.

Many bacteriologists have attempted to discover some certain method of isolating B. typhosus from substances rich in B. coli or coli-like microbes. The results have been disappointing. It is, however, too readily assumed that if such a method were forthcoming the B. coli test would sink into insignificance. This is hardly the truth, for even if a "magical medium" were discovered which, on the addition to it of a suspected water would, after incubation, turn, let us say, *red* only if B. typhosus were present, and *blue* if this microbe were absent, the B. coli test would still remain of value. For waters *known* to be sewage-polluted can hardly be assumed *always* to contain B. typhosus, or to contain this microbe in a virulent condition even in a large volume of such waters. Under these circumstances the "magical medium" might suggest "safety," but safety only so far as the particular volume of water actually submitted to cultural test was concerned, whereas the B. coli test may be trusted to measure the degree of excremental pollution and so indirectly the degree of danger * to health. Moreover, on mathematical lines of reasoning, the degree of liability of an excrementally polluted water to change from potential to actual danger would, other things being equal, be proportional to the number of B. coli present. So that whatever the future may have in store in the way of discovery of new and valuable methods for the isolation and detection of B. typhosus, the B. coli test is likely to remain of permanent value as the best means of measuring the degree of excremental pollution of water.

SECTION 1.

Morphological and Biological Characters of 101† B. coli derived from Normal Human Fæces.

Methods.

The following is a description of the methods adopted in this part of the investigation.

The stools were examined immediately after being passed.

Dilution:—

(*a*) 1 gramme of fæces was mixed thoroughly with 99 c.c. of sterile water in a sterile mortar. This dilution was called dilution A Each c.c. of the mixture represented ·01 gramme of fæces.

(*b*) 10 c.c. (·1 gramme of fæces) of dilution A was added by means of a sterilised 10 c.c. pipette to 90 c.c. of sterile water contained in a flask. This dilution was called dilution [3] because each c.c. of the mixture represented ·001 gramme of fæces.

(*c*) 10 c.c. (·01 gramme of fæces) of dilution [3] was transferred in a similar way to another flask containing 90 c.c. of sterile water. This dilution was called dilution [4] because each c.c. of the mixture represented ·0001 gramme of fæces.

(*d*) 10 c.c. (·001 gramme of fæces) of dilution [4] was added to another flask containing 90 c.c. of sterile water. This dilution was called dilution [5] because each c.c. represented ·00001 gramme of fæces.

(*e*) 10 cc. (·0001 gramme of fæces) of dilution [5] was added to another flask containing 90 c.c. of sterile water. This dilution was called dilution [6] because each c.c. represented ·000001 gramme of fæces.

---

* Potential danger, it is true, but liable on occasion to become actual.

† 102 microbes were actually isolated, but microbe No. 22 was discarded. It follows that microbes 1 to 21 (inclusive) and microbes 23 to 102 (inclusive) were eventually studied—that is, 101 specimens of B. coli in all.

(*f*) 10 c.c. (·00001 gramme of fæces) of dilution [6] was added to another flask containing 90 c.c. of sterile water. This dilution was called dilution [7] because each c.c. represented ·0000001 gramme of fæces.

(*g*) 10 c.c. (·000001 gramme of fæces) of dilution [7] was added to another flask containing 90 c.c. of sterile water. This dilution was called dilution [8] because each c.c. represented ·00000001 gramme of fæces.

(*h*) 10 c.c. (·0000001 gramme of fæces) of dilution [8] was added to another flask containing 90 c.c. of sterile water. This dilution was called dilution [9] because each c.c. represented ·000000001 gramme of fæces.

(*i*) 10 c.c. (·00000001 gramme of fæces) of dilution [9] was added to another flask containing 90 c.c. of sterile water. This dilution was called dilution [10] because each c.c. represented ·0000000001 gramme of fæces.

The amount of fæces in 1 c.c. of each of the above dilutions is shown in the following table :—

Dilution.	Each c.c. represents the following Fractions of a Gramme of Fæces :—		To obtain Results per Gramme of Fæces Multiply Results by :—
A	$\frac{1}{100}$	·01	100
[3]	$\frac{1}{1000}$	·001	1,000
[4]	$\frac{1}{10000}$	·0001	10,000
[5]	$\frac{1}{100000}$	·00001	100,000
[6]	$\frac{1}{1000000}$	·000001	1,000,000
[7]	$\frac{1}{10000000}$	·0000001	10,000,000
[8]	$\frac{1}{100000000}$	·00000001	100,000,000
[9]	$\frac{1}{1000000000}$	·000000001	1,000,000,000
[10]	$\frac{1}{10000000000}$	·0000000001	10,000,000,000

Broth cultures were made from the several dilutions, 1 c.c. being used in each instance. After incubation at 37° C. for two days, surface gelatine plate cultures from the broth cultures were made. These gelatine plate cultures were incubated at 20° C. On the second day they were examined, and the subsequent procedure was as follows :—

The last three plates from the last three dilutions showing the presence of colonies of B. coli were selected, and *two typical-looking colonies* from each plate were sub-cultured, The colonies of B. coli occurring in the highest or last dilution in which B. coli was present were called $\frac{\text{L. D.}}{1}$ B. coli (*i.e.* B. coli representing the last dilution). Those occurring in the plate next in the scale of dilutions were called $\frac{\text{L. D.}}{10}$ B. coli (*i.e.*, B. coli representing the last dilution but one). Those occurring in the plate last but two in the scale of dilutions were called $\frac{\text{L. D.}}{100}$ B. coli (*i.e.*, B. coli representing the next but one to the last dilution). To take an example :—1 c.c. broth cultures were made from dilutions [3], [4], [5], [6], [7], [8], [9], [10], and numbered in correspondence. Examined on the second day cultures [8], [9], [10] showed

TABLE I.—SHOWING the CHIEF MORPHOLOGICAL and BIOLOGICAL CHARACTER of 101 B. coli isolated from the STOOLS of HEALTHY PERSONS.

Cols. 1. Descriptive number of B. coli.	2. Stool.	3. Dilution LD/1, LD/10, LD/100 (for explanation see text).	4. Relative abundance of each strain of B. coli. Isolated by primary broth and secondary gelatine plate method from — Decimals of a gramme.	5. Type of colony in gelatine plate culture.	6. Motility. + = motile; ? – = not observed to be motile.	7. Gas in ordinary gelatine "shake" culture, 24 hours at 20° C.	8. Glucose, 1 %; peptone, 2 %; litmus medium. G. = gas; A. = acid; 2 days at 37° C.	9. Lactose, 1 %; peptone, 2 %; litmus medium. G. = gas; A. = acid; 2 days at 37° C.	10. Cane sugar, 1 %; peptone, 2 %; litmus medium. G. = gas; A. = acid; 2 days at 37° C.	11. Dulcit, 1 %; peptone, 2 %; litmus medium. Bl. = bleached; G. = gas; 2 days at 37° C.	12. Neutral red broth medium; + = fluorescence; 2 days at 37° C.	13. Indol in broth cultures; + = indol; 5 days at 37° C.	14. Litmus milk cultures. A. = acid; C. = clot; 5 days at 37° C.	15. Lactose, 1 %; peptone, 2 %; bile salt medium. G. = gas; A. = acid; C. = clot.	16. Growth on potato, 4 days at 37° C.	17. Nitrate broth; + = reduction of nitrate, 5 days at 37° C.	18. Proskauer & Capaldi medium No. I. Ac. = acid; 24 hours at 37° C.	19. Proskauer & Capaldi medium No. II. Bl. = bleached.	20. Litmus whey cultures. Acidity in terms of c.c. $\frac{N}{10}$ Na. CO_3 required to neutralise 100 c.c. of the medium.	21. Virulence. Broth cultures, 2 days growth at 37° C.; 1 c.c. injected subcutaneously into guinea-pig. + = death within 48 hours.	22. Liquefaction of gelatine, 30 days at 20° C.	23. Agglutination test.* Antityphoid guinea-pig serum. Dilution 1 : 20, 1 hour.	24. Agglutination test. Antityphoid horse serum. Dilution 1 : 20, 1 hour.	25. Agglutination test. Serum of person supplying B. coli. Dilution 1 : 20, 1 hour.	26. Agglutination test. Serum of person not supplying B. coli. Dilution 1 : 20, 1 hour.
1	I.	LD/1	·0000001	Filmy	? –	+	G. A.	G. A.	Negative	Negative	+	+	A. C.	G. A. C.	Slight growth, fawn coloured.	–	Ac.	Bl.	36	Non-virulent		Negative	Negative	Negative	Negative.
2	,,	,,	·0000001	Intermediate	+	+	G. A.	G. A.	G. A. (delayed and slight).	Ditto	+	+	A. C.	G. A. C.	Glistening, almost colourless growth.	–	Ac.	Bl.	37	Ditto		Negative	Negative	Negative	Negative.
3	,,	LD/10	·000001	Filmy	+	+	G. A.	Negative	Negative	Ditto	+	+	A. C.	Bl. No gas. No clot.	Slight growth, fawn coloured.	–	Ac.	Bl.	† No acid, † neutral.	+		Negative	Negative	Negative	Negative.
4	,,	,,	·000001	Intermediate	+	+	G. A.	Ditto	Ditto	Ditto	+	+	A. C.	Bl. No gas. No clot.	Creamy dirty yellowish white coloured growth.	–	Ac.	Bl.	† No acid, † neutral.	+		Negative	Negative	Negative	Negative.
5	,,	LD/100	·00001	Filmy	+	+	G. A.	Ditto	G. A. (delayed and slight).	Ditto	+	+	Slight A. No C.	Bl. No gas. No clot.	Creamy dirty yellowish white coloured growth.	–	Ac.	Bl.	† No acid, bleached, † neutral.	Non-virulent		Negative	Negative	Negative	Negative.
6	,,	,,	·00001	Intermediate	+	+	G. A.	G. A. (delayed).	Negative	Ditto	+	+	A. C.	G. A. C. (delayed).	Slight growth, fawn coloured.	+	Ac.	Bl.	† No acid, † neutral.	Ditto		Negative	Negative	Negative	Negative.
7	II.	LD/1	·00001	Opaque	+	+	G. A.	G. A.	Ditto	Bl. G.	+	+	A. C.	G. A. C.	Medium growth, dirty fawn colour.	+	Ac.	Bl.	41	Ditto		Negative	Negative	Negative	Negative.
8	,,	,,	·0000001	Opaque	+	+	G. A.	G. A.	Ditto	Bl. G.	+	+	A. C.	G. A. C.	Medium growth, dirty fawn colour.	+	Ac.	Bl.	43	Ditto		Negative	Negative	Negative	Negative.
9	,,	LD/10	·0000001	Filmy	+	+	G. A.	G. A.	Ditto	Bl. G.	+	+	A. C.	G. A. C.	Medium growth, dirty fawn colour.	+	Ac.	Bl.	40	Ditto		Negative	Negative	Suspicion of clumping	Suspicion of clumping.
10	,,	,,	·000001	Opaque	? –	+	G. A.	G. A.	Ditto	Negative	+	+	A. C.	G. A. C.	Medium growth, dirty fawn colour.	+	Ac.	Bl.	40	Ditto		Negative	Negative	Negative	Negative.
11	,,	LD/100	·00001	Filmy	+	+	G. A.	G. A.	Ditto	Bl. G.	+	+	A. C.	G. A. C.	Medium growth, dirty fawn colour.	+	Ac.	Bl.	38	Ditto		Negative	Negative	Suspicion of clumping	Negative.
12	,,	,,	·00001	Opaque	–	+	G. A.	G. A.	Ditto	Bl. G.	+	+	A. C.	G. A. C.	Medium growth, dirty fawn colour.	+	Ac.	Bl.	39	Ditto		Negative	Negative	Negative	Negative.
13	III.	LD/1	·000001	Filmy	–	+	G. A.	G. A.	Ditto	Bl. G.	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	34	Ditto		Negative	Positive but incomplete.	Positive (1 : 80 negative)	Positive (1 : 80 negative).
14	,,	,,	·000001	Filmy	+	+	G. A.	G. A.	Ditto	Bl. G.	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	34	Ditto		Negative	Positive but incomplete.	Positive (1 : 80 negative)	Positive (1 : 80 negative).
15	,,	LD/10	·00001	Filmy	+	+	G. A.	G. A.	A. No G.	Bl. G.	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	42	Ditto		Negative	Negative	Negative	Suspicion of clumping.
16	,,	,,	·00001	Filmy	+	+	G. A.	G. A.	A. Trace G.	Bl. G.	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	39	Ditto		Negative	Negative	Negative	Partial clumping.
17	,,	LD/100	·0001	Filmy	+	+	G. A.	G. A.	A. Trace G.	Bl. G.	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	41	Ditto		Negative	Negative	Suspicion of clumping	Positive (1 : 80 negative).
18	,,	,,	·0001	Opaque	+	+	G. A.	G. A.	Negative	Bl. G.	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	40	Ditto		Negative	Negative	Negative	Suspicion of clumping.
19	IV.	LD/1	·00000001	Intermediate	? –	+	G. A.	G. A.	Ditto	Negative	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	36	Ditto		Negative	Negative	Negative	Negative.
20	,,	,,	·00000001	Intermediate	?	+	G. A.	G. A.	G. A.	Ditto	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	42	Ditto		Negative	Negative	Negative	Negative.
21	,,	LD/10	·0000001	Filmy	+	+	G. A.	Bl. Trace G.	G. A.	Bl. No G.	+	+	A. No C.	Bl. No G. Slight C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	17	+		Negative	Negative	Negative	Negative.
22	,,	,,	This microbe gave no gas in gelatine "shake" culture, and on further study was found to be quite unlike B. coli.																						
23	,,	LD/100	·000001	Filmy	+	+	G. A.	G. A.	Negative	Negative	+	+	A. C.	G. A. C.	Slight growth, dirty yellowish cream colour.	+	Ac.	Bl.	40	Non-virulent		Negative	Negative	Negative	Negative.
24	,,	,,	·000001	Filmy	+	+	G. A.	G. A.	G. A.	Ditto	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	40	Ditto		Negative	Negative	Negative	Suspicion of clumping.
25	V.	LD/1	·000001	Filmy	+	+	G. A.	G. A.	Bl. G.	Bl. G.	+	+	A. C.	G. A. C.	Medium growth, dirty brownish cream colour.	+	Ac.	Bl.	40	Ditto		Negative	Negative	Suspicion of clumping	Negative.
26	,,	,,	·000001	Filmy	+	+	G. A.	G. A.	Bl. G.	Bl. G.	+	+	A. C.	G. A. C.	Slight growth, pale yellowish white colour.	+	Ac.	Bl.	40	+		Negative	Negative	Negative	Negative.
27	,,	LD/10	·000001	Filmy	+	+	G. A.	G. A.	Bl. G.	Bl. G.	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	40	+		Negative	Practically negative	Positive (1 : 80 suspicious).	Positive (1 : 80 negative).
28	,,	,,	·00001	Filmy	+	+	G. A.	G. A.	Bl. Slight G.	Bl. G.	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	42	+		Negative	Negative	Positive (1 : 80 suspicious).	Positive (1 : 80 negative).
29	,,	LD/100	·0001	Filmy	+	+	G. A.	G. A.	Bl. Slight G.	Bl. G.	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	38	Non-virulent		Negative	Negative	Positive (1 : 80 negative)	Positive (1 : 80 negative).
30	,,	,,	·0001	Opaque	+	+	G. A.	G. A.	Bl. G.	Bl. G.	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	40	Ditto		Negative	Negative	Negative	Negative.
31	VI.	LD/1	·00001	Filmy	+	+	G. A.	G. A.	Negative	Negative	+	+	A. C.	G. A. C.	Transparent, barely visible growth.	+	Ac.	Bl.	41	Ditto		Negative †	Practically negative †	Doubtful clumping †	Positive 1 : 20 sera of two individuals (1 : 100 negative with both).†
32	,,	,,	·000001	Filmy	? –	+	G. A.	G. A.	Ditto	Ditto	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	48	Ditto		Negative †	Practically negative †	Fair clumping †	Positive 1 : 20 sera of two persons.†
33	,,	LD/10	·00001	Filmy	+	+	G. A.	G. A.	Ditto	Ditto	+	+	A. C.	G. A. Slight C.	Slight growth, dirty yellowish cream colour.	+	Ac.	Bl.	32	Ditto		Negative	Suspicion of clumping	Suspicion of clumping	Sera of two persons indication of clumping (1 : 20). Serum of another person fair clumping 1 : 20, but negative 1 : 100.
34	,,	,,	·0001	Filmy	+	+	G. A.	G. A.	Ditto	Ditto	+	+	A. C.	G. A. Slight C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	34	Ditto		Negative	Suspicion of clumping	Suspicion of clumping	Sera of two persons tested—one negative, the other indication of clumping.
35	,,	LD/100	·001	Filmy	? –	+	G. A.	G. A.	Ditto	Negative	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	42	Ditto		Negative †	Some clumping but complete not quite satisfactory.†	Indication of clumping but incomplete.†	Sera of two persons tested—one indication, the other good clumping.†
36	,,	,,	·001	Filmy	? –	+	G. A.	G. A.	Ditto	Ditto	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	39	Ditto		Negative †	Slight indication of clumping.†	Indication of clumping but incomplete.†	Sera of two persons tested—one indication, the other good clumping.†
37	VII.	LD/1	·00001	Filmy	? –	+	G. A.	G. A.	Bl. Slight G.	Bl. G.	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	42	Ditto		Negative	Negative	Negative	Negative, sera of two persons.
38	,,	,,	·0001	Filmy	+	+	G. A.	G. A.	Bl. Slight G.	Ditto	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	35	Ditto		Negative	Practically negative	Negative	Negative, sera of two persons.
39	,,	LD/10	·0001	Filmy	+	+	G. A.	G. A.	Bl. Slight G.	Ditto	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	38	Ditto		Negative	Practically negative	Positive 1 : 100 practically negative.	Practically negative, sera of two persons.
40	,,	,,	·001	Filmy	+	+	G. A.	G. A.	Bl. Slight G.	Ditto	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	38	Ditto		Negative	Negative	Positive 1 : 100 practically negative.	Negative, sera of two persons.
41	,,	LD/100	·001	Filmy	+	+	G. A.	G. A.	Bl. Slight G.	Bl. G.	+	+	A. C.	G. A. C.	Slight, almost transparent growth.	+	Ac.	Bl.	42	Ditto		Negative	Positive 1 : 200, 1 : 800 incomplete 1 hour.	Indication of clumping	Distinct clumping.
42	,,	,,	·001	Filmy	+	+	G. A.	G. A.	Bl. Slight G.	Negative	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	37	Ditto		Negative	Negative	Distinct clumping	Distinct clumping.
43	VIII.	LD/1	·000001	Filmy	+	+	G. A.	G. A.	Bl. No G.	Bl. G.	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	39	Ditto		Negative	Negative	Negative	Negative.
44	,,	,,	·000001	Opaque	+	+	G. A.	G. A.	Bl. No G.	Negative	+	+	A. C.	G. A. C.	Slight growth, dirty yellowish cream colour.	+	Ac.	Bl.	38	Ditto		Negative	Some clumping but incomplete.	Practically negative	Negative.
45	,,	LD/10	·00001	Filmy	+	+	G. A.	G. A.	Bl. No G.	Ditto	+	+	A. C.	G. A. C.	Slight growth, dirty yellowish cream colour.	+	Ac.	Bl.	37	+		Negative	Some clumping but incomplete.	Strongly positive	Strongly positive.
46	,,	,,	·00001	Opaque	+	+	G. A.	G. A.	Bl. No G.	Ditto	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	39	Non-virulent		Negative	Indication but quite incomplete.	Practically negative	Practically negative
47	,,	LD/100	·0001	Filmy	+	+	G. A.	G. A.	Bl. No G.	Ditto	+	+	A. No C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	39	+		Negative	Fair clumping but incomplete.	Fair clumping	Fair clumping.
48	,,	,,	·0001	Filmy	+	+	G. A.	G. A.	Bl. No G.	Ditto	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	38	+		Negative	Indication of clumping but quite incomplete.	Fair clumping	Distinct clumping.
49	IX.	LD/1	·00000001	Opaque	? –	+	G. A.	G. A.	Negative	Ditto	+	+	A. C.	G. A. C.	Slight growth, dirty yellowish cream colour.	+	Ac.	Bl.	35	Non-virulent		Negative	Negative	Negative	Negative.‡
50	,,	,,	·00000001	Opaque	+	+	G. A.	G. A.	Ditto	Ditto	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	33	Ditto		Negative	Negative	Negative	Negative.‡
51	,,	LD/10	·0000001	Filmy	+	+	G. A.	G. A.	Bl. Slight G.	Bl. G.	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	36	Ditto		Indication. ? Negative.	Negative	Positive 1 : 20, 1 : 100 negative.	Practically negative.‡
52	,,	LD/10	·0000001	Filmy	+	+	G. A.	G. A.	Bl. Slight G.	Bl. G.	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	38	Ditto	None of the microbes liquefied gelatine.	Negative	Negative	Suspicion of clumping	Practically negative.‡
53	,,	LD/100	·000001	Filmy	+	+	G. A.	G. A.	Negative	Negative	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	38	Ditto		Negative	Negative	Negative	Negative
54	,,	,,	·000001	Filmy	+	+	G. A.	G. A.	Ditto	Ditto	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	38	Ditto		Negative	Negative	Negative	Negative.‡
55	X.	LD/1	·0000000001	Filmy	+	+	G. A.	G. A.	Bl. No G.	Ditto	+	—	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	41	Ditto		Negative	Negative	Negative	Negative.‡
56	,,	,,	·0000000001	Filmy	+	+	G. A.	G. A.	Bl. No G.	Ditto	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	38	Ditto		Negative	Negative	Negative	Negative.‡
57	,,	LD/10	·000000001	Filmy	+	+	G. A.	G. A.	Negative	Bl. G.	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	37	Ditto		Positive 1 : 20 instantaneous, 1 : 50 complete in less than ½ hour, 1 : 100 incomplete clumping in 1 hour.	Suspicion of clumping but incomplete.	Positive 1 : 20 instantaneous, 1 : 100 indication but incomplete in 1 hour.	Positive 1 : 20 sera of two persons, 1 : 100 negative in both cases.
58	,,	,,	·000000001	Filmy	+	+	G. A.	G. A.	Ditto	Bl. G.	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	38	Ditto		Positive same result as 57.	Suspicion of clumping but incomplete.	Positive 1 : 20 instantaneous, 1 : 100 indication but incomplete in 1 hour.	Positive 1 : 20 sera of two persons 1 : 100 negative in both cases.
59	,,	LD/100	·00000001	Filmy	+	+	G. A.	G. A.	Bl. Slight G.	Negative	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	41	Ditto		Negative	Negative	Negative	Negative.‡
60	,,	,,	·00000001	Filmy	+	+	G. A.	G. A.	Bl. Slight G.	Ditto	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	40	Ditto		Negative	Negative	Negative	Negative.‡
61	XI.	LD/100	·001	Filmy	+	+	G. A.	G. A.	Bl.	Bl. G.	+	+	A. C.	G. A. C.	Medium growth, dirty brownish cream colour.	+	Ac.	Bl.	28	Ditto		Negative	Negative	Negative	Negative.
62	,,	,,	·001	Filmy	+	+	G. A.	G. A.	Bl.	Bl. G.	+	+	A. C.	G. A. C.	Medium growth, orange brown colour.	+	Ac.	Bl.	36	Ditto		Negative	Negative	Negative	Negative.
63	,,	LD/10	·0001	Filmy	+	+	G. A.	G. A.	Bl.	Bl. G.	+	+	A. C.	G. A. C.	Medium growth, orange brown colour.	+	Ac.	Bl.	30	Ditto		Negative	Negative	Negative	Negative.
64	,,	,,	·0001	Filmy	+	+	G. A.	G. A.	Bl.	Bl. G.	+	+	A. C.	G. A. C.	Medium growth, dirty brownish cream colour.	+	Ac.	Bl.	35	Ditto		Negative	Negative	Negative	Negative.
65	,,	LD/1	·00001	Filmy	+	+	G. A.	G. A.	Bl.	Bl. G.	+	+	A. C.	G. A. C.	Medium growth, orange brown colour.	+	Ac.	Bl.	30	Ditto		Negative	Negative	Negative	Negative.
66	,,	,,	·00001	Filmy	+	+	G. A.	G. A.	Bl.	Bl. G.	+	+	A. C.	G. A. C.	Medium growth, dirty brownish cream colour.	+	Ac.	Bl.	31	Ditto		Negative	Negative	Negative	Negative.
67	XII.	LD/100	·00001	Filmy	+	+	G. A.	G. A.	Bl.	Bl. G.	—	+	A. C.	G. A. C.	Medium growth, dirty brownish cream colour.	+	Ac.	Bl.	30	Ditto		Negative	Negative	Negative	Negative.
68	,,	,,	·00001	Filmy	+	+	G. A.	G. A.	Bl.	Negative	+	+	A. C.	G. A. C.	Medium growth, dirty brownish cream colour.	+	Ac.	Bl.	37	Ditto		Negative	Negative	Negative	Negative.
69	,,	LD/10	·000001	Filmy	+	+	G. A.	G. A.	Bl. Practically no gas.	Bl. G.	—	+	A. C.	G. A. C.	Medium growth, orange brown colour.	+	Ac.	Bl.	30	Ditto		Negative	Negative	Negative	Negative.
70	,,	,,	·000001	Filmy	+	+	G. A.	G. A.	Bl.	Bl. G.	+	+	A. C.	G. A. C.	Transparent, barely visible growth.	+	Ac.	Bl.	28	Ditto		Negative	Negative	Negative	Negative.
71	,,	LD/1	·0000001	Filmy	+	+	G. A.	G. A.	Bl.	Bl. G.	+	—	A. C.	G. A. C.	Medium growth, dirty brownish cream colour.	+	Ac.	Bl.	29	Ditto		Negative	Negative	Negative	Negative.
72	,,	,,	·0000001	Filmy	+	+	G. A.	G. A.	Bl.	Bl. G.	+	+	A. C.	G. A. C.	Medium growth, dirty brownish cream colour.	+	Ac.	Bl.	30	Ditto		Negative	Negative	Negative	Negative.
73	XIII.	LD/100	·001	Opaque	+	+	G. A.	G. A.	Bl.	Negative	+	+	A. C.	G. A. C.	Glistening, almost colourless growth.	+	Ac.	Bl.	40	Ditto		Negative	Negative	Negative	Negative.
74	,,	,,	·001	Opaque	+	+	G. A.	G. A.	Bl.	Ditto	+	+	A. C.	G. A. C.	Creamy growth, dirty yellowish white colour.	+	Ac.	Bl.	39	Ditto		Negative	Negative	Negative	Negative.
75	,,	LD/10	·0001	Opaque	+	+	G. A.	G. A.	Bl.	Bl. G.	+	+	A. C.	G. A. C.	Glistening, almost colourless growth.	+	Ac.	Bl.	32	Ditto		Negative	Negative	Negative	Positive 1 : 20, negative 1 : 100.
76	,,	,,	·0001	Opaque	+	+	G. A.	G. A.	Bl.	Negative	+	+	A. C.	G. A. C.	Glistening, almost colourless growth.	+	Ac.	Bl.	36	Ditto		Negative	Negative	Negative	Negative.
77	,,	LD/1	·00001	Opaque	+	+	G. A.	G. A.	Bl.	Bl. G.	+	+	A. No C.	G. A. C.	Creamy growth, fawn coloured.	+	Ac.	Bl.	32	Ditto		Negative	Negative	Negative	Positive 1 : 20, negative 1 : 100.
78	,,	,,	·00001	Opaque	+	+	G. A.	G. A.	Bl.	Bl. G.	+	+	A. No C.	G. A. C.	Creamy growth, faint yellow colour.	+	Ac.	Bl.	32	Ditto		Negative	Negative	Negative	Positive 1 : 20, negative 1 : 100.
79	XIV.	LD/10	·001	Filmy	+	+	G. A.	G. A.	Negative	Negative	+	+	A. C.	G. A. C.	Moderate growth, dirty fawn colour.	+	Ac.	Bl.	40	Ditto		Negative	Negative	Negative	Negative.
80	,,	,,	·001	Filmy	+	+	G. A.	G. A.	Bl. No G.	Ditto	+	+	A. C.	G. A. C.	Moderate growth, dirty fawn colour.	+	Ac.	Bl.	39	Ditto		Negative	Negative	Negative	Negative.
81	,,	LD/10	·0001	Filmy	+	+	G. A.	G. A.	Bl. No G.	Ditto	+	+	A. C.	G. A. C.	Moderate growth, dirty fawn colour.	+	Ac.	Bl.	38	Ditto		Negative	Negative	Negative	Negative.
82	,,	,,	·0001	Filmy	+	+	G. A.	G. A.	Negative	Ditto	+	+	A. C.	G. A. C.	Moderate growth, dirty fawn colour.	+	Ac.	Bl.	40	Ditto		Negative	Negative	Negative	Negative.
83	,,	LD/1	·00001	Filmy	+	+	G. A.	G. A.	Ditto	Ditto	+	+	A. C.	G. A. C.	Moderate growth, dirty fawn colour.	+	Ac.	Bl.	39	Ditto		Negative	Negative	Fair clumping, 1 : 20; negative 1 : 100.	Fair clumping.
84	,,	,,	·00001	Opaque	? –	+	G. A.	G. A.	Ditto	Ditto	+	+	A. C.	G. A. C.	Moderate growth, dirty fawn colour.	+	Ac.	Bl.	37	Ditto		Negative	Negative	Negative	Negative.
85	XV.	LD/100	·0001	Filmy	+	+	G. A.	G. A.	Bl. Slight G.	Bl. G.	+	+	A. C.	G. A. C.	Moderate growth, dirty fawn colour.	+	Ac.	Bl.	33	Ditto		Negative	Negative	Slight clumping	Suspicion of clumping.
86	,,	,,	·0001	Filmy	+	+	G. A.	G. A.	Bl. No G.	Bl. G.	+	+	A. C.	G. A. C.	Slight growth, dirty white colour.	+	Ac.	Bl.	36	Ditto		Negative	Negative	Slight clumping	Negative.
87	,,	LD/10	·00001	Filmy	+	+	G. A.	G. A.	Bl. Slight G.	Bl. G.	+	+	A. C.	G. A. C.	Moderate growth, dirty fawn colour.	+	Ac.	Bl.	37	Ditto		Negative	Negative	Suspicion of clumping	Suspicion of clumping.
88	,,	,,	·00001	Filmy	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] growth, dirty fawn colour.	+	Ac.	Bl.	35	Ditto		Negative	Negative	Fair clumping	Slight clumping.
89	,,	LD/1	·000001	Filmy	+	+	G. A.	G. A.	Bl. Slight G.	Bl. G.	+	+	A. C.	G. A. C.	Creamy growth, dirty fawn colour.	+	Ac.	Bl.	37	Ditto		Negative	Negative	Suspicion of clumping	[illegible]
90	,,	,,	·000001	Filmy	+	+	G. A.	G. A.	Bl. Slight G.	Bl. G.	+	+	A. C.	G. A. C.	Creamy growth, dirty fawn colour.	+	Ac.	Bl.	37	Ditto		Negative	Negative	Negative	Suspicion of clumping.
91	XVI.	LD/100	·00001	Filmy	+	+	G. A.	G. A.	Bl.	Bl. G.	+	+	A. C.	G. A. C.	Copious growth, dirty fawn colour.	+	Ac.	Bl.	33	Ditto §		Negative	Negative	Practically negative	Negative.
92	,,	,,	·00001	Filmy	+	+	G. A.	G. A.	Bl.	Bl. G.	+	+	A. C.	G. A. C.	Moderate growth, dirty fawn colour.	+	Ac.	Bl.	31	Ditto §		Negative	Negative	Negative	Negative.
93	,,	LD/10	·000001	Filmy	+	+	G. A.	G. A.	Bl. Practically no gas.	Bl. G.	+	+	A. C.	G. A. C.	Moderate growth, dirty fawn colour.	+	Ac.	Bl.	33	Ditto §		Negative	Negative	Negative	Negative.
94	,,	,,	·000001	Filmy	+	+	G. A.	G. A.	Bl.	Bl. G.	+	+	A. C.	G. A. C.	Slight growth, dirty reddish brown colour.	+	Ac.	Bl.	33	Ditto §		Negative	Negative	Negative	Negative.
95	,,	LD/1	·0000001	Filmy	+	+	G. A.	G. A.	Bl.	Bl. G.	+	+	A. C.	G. A. C.	Moderate growth, dirty fawn colour.	+	Ac.	Bl.	31	Ditto §		Negative	Negative	Negative	Negative.
96	,,	,,	·0000001	Filmy	+	+	G. A.	G. A.	Bl.	Bl. G.	+	+	A. C.	G. A. C.	Slight growth, dirty fawn colour.	+	Ac.	Bl.	31	Ditto §		Negative	Negative	Negative	Negative.
97	XVII.	LD/100	·00000001	Filmy	+	+	G. A.	G. A.	Bl. Slight G.	Bl. G.	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	37	Ditto §		Negative	Negative	Negative	Negative.
98	,,	,,	·00000001	Filmy	+	+	G. A.	G. A.	Bl. Slight G.	Bl. G.	+	+	A. C.	G. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	37	Ditto §		Negative	Negative	Negative	Negative.
99	,,	LD/10	·000000001	Filmy	+	+	G. A.	G. A.	Negative	Bl. G.	+	+	A. No C.	C. A. C.	Medium growth, dirty yellowish cream colour.	+	Ac.	Bl.	40	Ditto §		Negative	Negative	Negative	Negative.
100	,,	,,	·000000001	Filmy	+	+	G. A.	A. Slight G.	Ditto	Bl. G.	+	+	A. No C.	Bl. No G. No C.	Medium growth, dirty yellowish cream colour.	+	Slight Ac.	Bl.	29	Ditto §		Negative	Negative	Negative	Negative.
101	,,	LD/1	·0000000001	Filmy	+	+	G. A.	A. Slight G.	Ditto	Bl. G.	+	+	A. No C.	Bl. Trace G. Slight C.	Medium growth, dirty yellowish cream colour.	+	Slight Ac.	Bl.	29	Ditto §		Negative	Negative	Negative	Negative.
102	,,	,,	·0000000001	Filmy	+	+	G. A.	A. Trace G.	Ditto	Bl. G.	+	+	A. No C.	Bl. Trace G. Slight C.	Medium growth, dirty yellowish cream colour.	+	Slight Ac.	Bl.	28	Ditto §		Negative	Negative	Negative	Negative.

* I have to acknowledge, with much gratitude, the assistance kindly given me by Dr. Schölberg in carrying out these agglutination experiments.
† Agar culture used for emulsion, in all other cases a gelatine culture was employed.
‡ B. Coli 49, 50, 51, 52, 53, 54, 55, 56, 59, 60 were also tested as regards agglutination with the serum of a normal guinea-pig (1 : 20 dilution, 1 hour). The result was quite negative except as regards 51 and 52. The former was clumped to a slight extent, and the latter gave a practically negative result.
§ Microbes 91 to 102 were also used to inoculate mice, 1 cc. of broth culture being injected subcutaneously in each case. Only microbe 102 proved to be virulent (death within 48 hours).

no growth. Plates were made from cultures [3], [4], [5], [6], [7], and numbered in correspondence. Examined on the second day plate [7] showed no colonies resembling B. coli. Plates [3], [4], [5], [6] showed colonies resembling those of B. coli. Plates [4], [5], [6], were selected for further study. Two typical colonies were sub-cultured from plate [6], each being called $\frac{\text{L. D.}}{1}$ B. coli. Similarly two colonies were sub-cultured from [5], each being called $\frac{\text{L. D.}}{10}$ B. coli. Lastly, two colonies were sub-cultured from plate [4], each being called $\frac{\text{L. D.}}{100}$ B. coli.

It is important to bear in mind (1) *that the typical-looking colonies of* B. coli *were selected for sub-culture,* and (2) that the *selection* was made *from* the plates *representing* the highest ($\frac{\text{L. D.}}{1}$), the *next highest* (one-tenth less, $\frac{\text{L. D.}}{10}$), and the *next* but one highest (one hundred less, $\frac{\text{L. D.}}{100}$) of the dilutions (*made in successive tenths in which B. coli was observed to be present*).

The B. coli isolated from the various stools obtained from healthy persons were subjected to nearly every known test of importance.

The tests employed may be summed up as follows :—

Motility.

Agglutination tests (anti-typhoid blood, Berne serum, normal human blood).

Pathogenicity, towards rodents.

Gelatine "shake" cultures, for gas formation.

Glucose peptone cultures,	For observation of acid production and fermentation.
Lactose peptone cultures,	
Dulcit peptone cultures,	
Cane-sugar peptone cultures,	

Broth cultures, for indol formation.

Litmus milk cultures, for acid clotting of the medium.

Lactose peptone milk cultures, for gas formation, acidity, and clotting.

Neutral red broth cultures, for greenish yellow fluorescence.

Potato cultures, for observation of mode of growth.

Litmus whey cultures, for quantitative estimation of acidity.

Nitrate broth cultures, for reduction of nitrates to nitrites.

Proskauer and Capaldi's Medium No. I, for production of cherry-red colour.

Proskauer and Capaldi's Medium No. II, for absence of definite acid formation.

The results are given in Tables 1 and 2.

TABLE 2, SHOWING THE RESULTS OF CERTAIN EXPERIMENTS WITH ANTI-COLI 57 AND 58 SERA.

Description of Microbe.	Agglutination Experiments.	
	Anti-coli 57 Serum.	Anti-coli 58 Serum.
Coli 57 - - -	1 : 200 almost instantaneous -	1 : 800 complete clumping.
	1 : 400 decided clumping - -	
„ 58 - - -	1 : 600 indication, but incomplete	1 : 1600 indication, but incomplete.
B. typhosus - - -	1 : 20 incomplete clumping - - -	1 : 20 incomplete clumping.
	1 : 200 practically negative - - -	1 : 200 practically negative.
Coli 31 - - - -	1 : 20 negative - - - - -	1 : 20 negative.
„ 33 - - - -	1 : 20 negative - - - - -	1 : 20 negative.
„ 34 - - - -	1 : 20 negative - - - - -	1 : 20 negative.
„ 37 - - - -	1 : 20 negative - - - - -	1 : 20 negative.
„ 38 - - - -	1 : 20 negative - - - - -	1 : 20 negative.
„ 39 - - - -	1 : 20 negative - - - - -	1 : 20 negative.
„ 40 - - - -	1 : 20 negative - - - - -	1 : 20 negative.
„ 49 - - - -	1 : 20 negative - - - - -	1 : 20 negative.
„ 50 - - - -	1 : 20 negative - - - - -	1 : 20 negative.
„ 51 - - -	1 : 20 slight indication - -	1 : 20 fair clumping.
	1 : 100 negative - - - -	1 : 100 negative.
„ 52 - - -	1 : 20 slight indication - -	1 : 20 fair clumping.
	1 : 100 negative - - - -	1 : 100 negative.
„ 53 - - -	1 : 20 strong positive - - -	1 : 20 fair clumping.
	1 : 100 indication - - -	1 : 100 negative.
„ 54 - - -	1 : 20 strong positive - - -	1 : 20 fair clumping.
	1 : 100 indication - - - -	1 : 100 negative.
„ 55 - - - -	1 : 20 negative - - - - -	1 : 20 negative.
„ 56 - - - -	1 : 20 negative - - - - -	1 : 20 negative.
„ 59 - - - -	1 : 20 negative - - - - -	1 : 20 negative.
„ 60 - - - -	1 : 20 negative - - - - -	1 : 20 negative.
„ 61 - - - -	1 : 20 negative - - - - -	1 : 20 negative.
„ 62 - - - -	1 : 20 negative - - - - -	1 : 20 negative.
„ 63 - - - -	1 : 20 negative - - - - -	1 : 20 negative.
„ 64 - - - -	1 : 20 negative - - - - -	1 : 20 negative.
„ 65 - - - -	1 : 20 negative - - - - -	1 : 20 negative.
„ 66 - - - -	1 : 20 negative - - - - -	1 : 20 negative.
„ 67 - - - -	1 : 20 negative - - - - -	1 : 20 negative.
„ 68 - - - -	1 : 20 negative - - - - -	1 : 20 negative.

TABLE 2, SHOWING THE RESULTS OF CERTAIN EXPERIMENTS WITH ANTI-COLI 57 AND 58 SERA—*continued.*

Description of Microbe.	Agglutination Experiments.	
	Anti-coli 57 Serum.	Anti-coli 58 Serum.
Coli 69	1 : 20 negative	1 : 20 negative.
„ 70	1 : 20 negative	1 : 20 negative.
„ 71	1 : 20 negative	1 : 20 negative.
„ 72	1 : 20 negative	1 : 20 negative.
„ 73	1 : 20 negative	1 : 20 negative.
„ 74	1 : 20 negative	1 : 20 negative.
„ 75	1 : 20 negative	1 : 20 negative.
„ 76	1 : 20 negative	1 : 20 negative.
„ 77	1 : 20 negative	1 : 20 negative.
„ 78	1 : 20 negative	1 : 20 negative.
„ 79	1 : 20 negative	1 : 20 negative.
„ 80	1 : 20 negative	1 : 20 negative.
„ 81	1 : 20 negative	1 : 20 negative.
„ 82	1 : 20 negative	1 : 20 negative.
„ 83	1 : 20 negative	1 : 20 negative.
„ 84	1 : 20 negative	1 : 20 negative.
„ 85	1 : 20 negative	1 : 20 negative.
„ 86	1 : 20 negative	1 : 20 negative.
„ 87	1 : 20 negative	1 : 20 negative.
„ 88	1 : 20 negative	1 : 20 negative.
„ 89	1 : 20 negative	1 : 20 negative.
„ 90	1 : 20 negative	1 : 20 negative.
„ 91	1 : 20 negative	1 : 20 negative.
„ 92	1 : 20 negative	1 : 20 negative.
„ 93	1 : 20 negative	1 : 20 negative.
„ 94	1 : 20 negative	1 : 20 negative.
„ 95	1 : 20 negative	1 : 20 negative.
„ 96	1 : 20 negative	1 : 20 negative.
„ 97	1 : 20 negative	1 : 20 negative.
„ 98	1 : 20 negative	1 : 20 negative.
„ 90	1 : 20 negative	1 : 20 negative.
„ 100	1 : 20 negative	1 : 20 negative.
„ 101	1 : 20 negative	1 : 20 negative.
„ 102	1 : 20 negative	1 : 20 negative.

Analysis of the results.

Dealing with the various columns in Table 1, *seriatim* :—

Column 1.—"*Identification*" *number of B coli.*

No comment is needed here.

Column 2.—*Stools I. to XVII.*

Here it is to be noted that although 17 stools were examined, stools I., IV., VI., XIII., and XV.; II. and V.; III. and X.; VII., VIII., and XIV.; XI., XII., and XVI., were derived from the same individuals. While in the report "the normal stools of healthy persons" is the term used, it will be understood that what is "normal" as regards stools and "healthy" in respect of the individual may not be capable of scientific definition. Broadly speaking, what is implied is—stools of medium consistency voided without artificial stimulus by persons in a state of apparent health carrying out their usual vocations. The stools were those of adult males, and they were examined immediately after having been passed.

Column 3.—$\frac{\text{L. D.}}{1}$; $\frac{\text{L. D.}}{10}$; $\frac{\text{L. D.}}{100}$.

By $\frac{\text{L. D.}}{1}$ is meant the last dilution of the stool yielding B. coli. $\frac{\text{L. D.}}{10}$ represents the dilution ten times lower, and $\frac{\text{L. D.}}{100}$ the dilution one hundred times lower in the scale of dilutions. Thus two microbes from each of the last three dilutions yielding B. coli in each of the 17 stools were selected for examination.

Column 4.—*Relative abundance of the* 101 *B. coli per gramme of fæces* :—

The results may be summed up as follows :—

10,000 million,	four	per cent.	Derived from 17 stools.
1,000 ,,	six	,, ,,	
100 ,,	nine	,, ,,	
10 ,,	sixteen	,, ,,	
1 ,,	twenty	,, ,,	
100 thousand,	twenty-four	per cent.	
10 ,,	fourteen	,, ,,	
1 ,,	eight	,, ,,	

Column 5.—*Type of B. coli colony in gelatine plate culture* (*filmy type, opaque type, intermediate type*) :—

The great majority were of the filmy type.

Notes of the morphological characters of the B. coli were also made; for example, whether the rods were long, short, or of medium length. But this is a matter which involves the personal equation, and depends moreover on the nature of the medium and other factors. Moreover, the gradations are so fine that it is almost impossible to give any classification of practical value. It has, therefore, been thought desirable not to utilise these records. But it is worth noting that in the majority of instances the B. coli isolated were distinctly cylindrical in shape, and seldom approached the type which in the phraseology of the past would be called "bacterium," that is, a microbe hardly longer than broad.

Column 6.—*Motility.*

For observations as regards motility gelatine cultures (24 hours at 20° C.) were used. Only 12 per cent. of the B. coli were non-motile, or not observed to be motile. It is difficult, of course, positively to assert that a microbe is non-motile. All perhaps that can be said is that it was not observed to be motile. Hence, in the table (column 6, Table 1) the sign ? – has been employed. The remainder, 89 per cent., were motile, and in the majority of cases the movement was rapid.

It is to be noted, however, that the non-motile B. coli were, generally speaking, by no means atypical in other respects, although some of them formed so unsatisfactory an emulsion that agar cultures (in place of gelatine cultures) had to be employed for the agglutination experiments. The non-motile B. coli were 1, 2, 10, 19, 20, 32, 34, 35, 36, 37, 49, and 84.

Column 7.—"*Gas*" *in gelatine* "*shake*" *culture* (within 24 hours at 20° C.).

All the 101 microbes gave "gas" in gelatine "shake" cultures within 24 hours at 20° C.*

Column 8.—*Glucose peptone medium.*

All of the 101 microbes produced gas and acid in this medium. This result was to be anticipated in view of the results set forth in column 7 ("gas" in gelatine "shake" cultures).

Column 9.—*Lactose peptone medium.*

No fewer than 92 per cent. of the B. coli yielded completely positive results (gas and acid within 48 hours at 37 deg. C.). Three of the 101 microbes gave entirely negative results, and the remainder only feebly positive results. Those yielding negative or only feebly positive results were usually atypical in one or more other respects. Thus microbes 3, 4, 5, and 6 produced no definite amount of acidity in litmus whey cultures, and atypical results in lactose peptone milk cultures. Microbe 5 did not clot milk. Microbe 21 gave no clot in litmus milk cultures, an atypical change in lactose peptone milk cultures, and, relatively speaking, feeble acidity in litmus whey cultivations. Microbes 100, 101, and 102 did not clot milk, behaved atypically in lactose peptone milk cultures, produced only slight acid in Proskauer and Capaldi medium No. I., and less than the average amount of acid in litmus whey cultures.

Column 10.—*Cane-sugar peptone medium.*

Only 8 per cent. yielded completely positive results; 35 per cent. gave quite negative results. Another 36 per cent. produced an acid change or a bleached appearance with which was associated either no gas formation or practically none. 20 per cent. gave rise to a bleached appearance with slight gas formation, and 2 per cent. showed a delayed and feeble power of fermenting the cane-sugar. Practically speaking the foregoing may be classed as follows:—

8	per cent.		strongly positive.
22	,,	,,	feebly positive.
36	,,	,,	query negative.
35	,,	,,	negative.

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* As previously explained, 102 microbes were actually isolated, but microbe No. 22 was discarded. It follows that microbes 1 to 21 (inclusive) and microbes 23 to 102 (inclusive) were eventually studied—that is, 101 specimens of B. coli in all.

It will be noticed that in this report the term B. coli *communis* has not been employed. The term communis, if used in a strict sense, implies a great deal; if employed in a loose sense it conveys so little that its value is very doubtful. B. coli *communis* dates its recognition as the characteristic microbe of fæces from the classical researches of Escherich. Escherich's B. coli communis *does not* ferment cane-sugar.

Column 11.—*Dulcit peptone medium.*

The value to be placed on this test is at present unknown, but it is obvious that by its use in this investigation the B. coli were sharply divided into two classes, namely, 45 per cent. giving rise to no change in the medium, and 55 per cent. producing gas and a bleached appearance of the liquid. 1 per cent. bleached but did not form gas.

Putting on one side the cane-sugar test, it is certain that over 90 per cent. of the coli-like microbes isolated during the inquiry would be classed as B. coli communis. But is it justifiable to place under one species, or even in the same group, microbes of which rather more than half ferment dulcit and rather less than half do not?

There seemed to be no definite relation between the "cane-sugar" and "dulcit" results; some coli-like microbes ferment both cane-sugar and dulcit, others cane-sugar and not dulcit, others dulcit and not cane-sugar; others again neither cane-sugar nor dulcit.

Further, it could not be said that the coli-like microbes which fermented dulcit differed, generally speaking, in respect of other tests from those which failed to do so.

The dulcit fermentation results seem to show that there may be less uniformity of species among the B. coli than might be supposed from the application of the other tests in general use among bacteriologists.

Column 12.—*Neutral red broth.*

The results were striking, inasmuch as no fewer than 98 per cent. of the coli-like microbes yielded positive results (greenish-yellow fluorescence within 48 hours). The two microbes (67 & 69) yielding negative results were seemingly typical in all other important respects.

Column 13.—*Indol test* (indol in broth cultures within 5 days at 37° C.).

This is an old and valuable test. Out of the 101 B. coli, only two failed to form indol. These two (55 & 71) in other important respects were seemingly typical of B. coli.

Column 14.—*Litmus milk cultures.*

Ninety-two per cent. of the coli-like microbes produced acidity and clotting within five days at 37° C. In the majority of cases clotting occurred within 48 hours. One microbe (5) gave no clot and only slight acidity. This micro-organism did not ferment lactose, produced an atypical change in lactose peptone milk cultures, and gave rise to no definite acidity in litmus whey. Eight microbes (21, 47, 77, 78, 99, 100, 101, 102) produced acid in but did not clot the milk.

B. coli No. 21 gave atypical results in lactose peptone and lactose peptone milk media, and a relatively small amount of acid in litmus whey culture.

Microbes 47, 77, 78, and 99 were seemingly typical in other important respects. Microbe 47 was virulent.

Microbes 100, 101, and 102 were not completely typical as regards the lactose peptone, lactose peptone milk, and Proskauer and Capaldi (No. 1) tests.

Column 15.—*Lactose peptone sodium carbonate milk medium.*

This test is useful. Within 24 to 48 hours at 37° C. typical B. coli produces in this medium acid, abundant gas, and clots the milk. The appearance of a typically changed culture is so striking that it is easy to eliminate atypical B. coli by its use. The alkalinity of the medium holds in check aberrant forms, but is powerless to prevent typical B. coli from producing in the medium acid, gas, and clot.

Ninety per cent. of the coli-like microbes isolated yielded completely positive results (gas, acid, and clot).

The rest gave results as follows :—

Bleached, no gas, no clot, four per cent. of total.

Bleached, slight clot, trace gas, two per cent.

Gas, acid, slight clot, two per cent.

Bleached, no gas, slight clot, one per cent.

Delayed gas, acid, and clot formation, one per cent.

The aberrant specimens of B. coli were :—Microbes 3, 4, 5, 6, 21, 33, 34, 100, 101, 102. Of these microbes 3, 4, 5, and 6 produced little or no acidity in litmus whey cultures, and microbe 5 failed to clot milk in ordinary litmus milk cultures. Microbes 3, 4, and 5 gave negative results in lactose peptone, and microbe 6 was atypical in this medium. Microbe 21 gave no clot in ordinary litmus milk cultures, and the acidity produced by it in litmus whey culture was much below the average. This microbe also yielded atypical results in lactose peptone. Microbes 33 and 34 yielded typical results in other media, but were atypical only to a slight extent in the medium under consideration. Microbes 100, 101, and 102 were atypical as regards the lactose peptone, ordinary litmus milk, and Proskauer and Capaldi (No. 1) tests.

While a glucose fermenting non-liquefying coli-like microbe which fails to produce gas, acid, and clot in this lactose milk medium within 24 to 48 hours at 37° C. cannot be said to be necessarily non-intestinal in origin, it nevertheless is obvious that an overwhelming majority of fæcal B. coli possess these powers.

Column 16.—*Growth on potato.*

As regards their growth on potato the coli isolated seemed to present every gradation from a transparent barely visible growth to an opaque luxuriant growth either of a dirty white or of a fawn, yellow, orange, or brown colour. The results do not lend themselves to any definite classification, as the appearances shaded off into each other by indefinable gradations. On the whole, however, the results showed somewhat strong indication that the B. coli belonged not to one but a number of different species. Thus even when cultures were made from the same batch of potatoes striking differences were noted in the growth of the various coli-like microbes despite the fact that as regards other tests no such dissimilarity could be detected.

The characters of the growth on potato, as a test for B. coli, is without much value. Even as a means of discriminating between B. coli and B. typhosus its utility is only relative. Indeed, about 7 per cent. of the coli-like microbes gave on potato a transparent barely visible growth.

Column 17.—*Nitrate broth.*

No less than 100 per cent. of the coli-like microbes reduced nitrates to nitrites.

Column 18.—*Proskauer and Capaldi medium* No. I.

Ninety-eight per cent. of the microbes gave a positive result—namely, a bright cherry red coloration within twenty-four hours at 37°C. Three microbes (100, 101, and 102) gave rise only to slight acidity in the medium. These micro-organisms gave atypical results also in lactose peptone, litmus milk, and lactose peptone milk cultures. This test (in conjunction with medium No. II.) has its highest value in discriminating between atypical B. coli and B. typhosus.

Column 19.—*Proskauer and Capaldi medium* No. II.

All the 101 B. coli gave rise to a bleached appearance without definite indication of acidity. Nevertheless, with a considerable proportion it was a question whether some degree of acidity was not produced, although the appearances were in no case such as would be likely to be confounded with the distinct acidity produced in this medium by B. typhosus. As previously explained, Proskauer and Capaldi's media are of most value in differentiating B. typhosus from the atypical members of the coli group. There is no difficulty in discriminating by the use of these media between typical B. coli and B. typhosus. This discrimination, however, is easily effected by a large number of other tests. The difficulty arises when we have to deal with aberrant forms of B. coli, and it is precisely these microbes which are most likely to create confusion alike in Proskauer and Capaldi's as in other media by their negative characters or lack of strength in respect of positive attributes.

Column 20.—*Litmus whey cultures.*

The results may be briefly summarised as follows :—

Ninety-six per cent. of the coli-like microbes required from 28 to 46 per cent. $\frac{N}{10}$ $Na_2\ CO_3$ to neutralise the acidity.

One microbe (21) required 17 per cent. $\frac{N}{10}$ $Na_2\ CO_3$.

Four microbes (3, 4, 5, and 6) produced little or no acidity.

Microbes 3, 4, 5, 6, and 21 were atypical in lactose peptone and in lactose peptone milk media, and microbes 5 and 21 did not clot milk.

It is obvious that an overwhelming majority of the coli-like microbes produced a large amount of acid in litmus whey cultures. As regards this test, as with the foregoing tests, the fæcal coli microbes were conspicuous by reason of the "strength of their positive attributes."

It would be saying too much to assert that a coli-like microbe not requiring less than 28 to 46 per cent. $\frac{N}{10}$ $Na_2\ CO_3$ to neutralise the acidity produced in litmus whey cultures was not intestinal in origin. Nevertheless, failure to reach this standard would not further the claim of a microbe to be regarded as B. coli.

Column 21.—*Virulence in broth cultures.*

Only nine of the 101 B. coli were found to be virulent in rodents. Many of the B. coli were pathogenic, inasmuch as they produced a swelling at the site of the inoculation accompanying non-fatal illness of the animal. But it was considered advisable to class all microbes as non-virulent which did not kill the guinea-pig within 48 hours when 1 c.c. of a two days' broth culture (incubated at 37° C.) had been injected subcutaneously.

Of the virulent B. coli some were not otherwise altogether typical: *e.g.*, microbes 3 and 4 did not ferment lactose and produced no definite acidity in litmus whey culture, and microbe 21 produced only a trace of gas in lactose peptone medium, an atypical change in lactose peptone milk medium no clot in litmus milk cultures, and a relatively small amount of acid in

litmus whey cultures. Microbe 47 did not clot milk. While in all important cases the inoculation of animals is to be recommended, the foregoing results do not seem to indicate that as a routine test for B. coli animal experiments are necessary or altogether justifiable. It is true that in this inquiry only normal stools have been dealt with, but in the bacterioscopic examination of water from a public health point of view it is impossible to discriminate between the B. coli derived from the excremental matters of healthy as compared with those of diseased persons.

Column 22.—Liquefaction of gelatine.

None of the 101 B. coli liquefied gelatine within 30 days. As a matter of fact, none of them have shown any liquefaction after the lapse of several months, but the limit arbitrarily fixed for observation was 30 days. But there are microbes apparently *coli-like* which slowly liquefy gelatine; microbes, moreover, which respond positively to some of the tests for B. coli. These microbes have been found not infrequently in polluted liquid and solid substances, and it may be that the presence of such microbes is not unassociated with objectionable contamination. Nevertheless, it cannot be said that a liquefying *coli-like* microbe is to be classed as typical B. coli. The difficulty, of course, is that liquefaction, when it occurs, is commonly very gradual, of the nature of a slow softening of the gelatine; and it is manifestly inconvenient in routine work to suspend judgment for a prolonged period while old cultures are kept under observation.

Agglutination Experiments.

Column 23.—Anti-typhoid guinea-pig serum (guinea pig immunised with living cultures of B. typhosus).

The dilution used was 1 : 20 ; the time of microscopic observation was one hour. The serum of the guinea-pig immunised as above, tested with B. typhosus, gave almost instantaneous clumping with a dilution of 1 : 50. When the dilution was 1 : 200 partial but incomplete clumping occurred.

Of the 101 B. coli no less than 98 gave a negative result. One (51) gave a slight indication (? negative) of clumping. Two (57 and 58) yielded strongly positive results, yet appeared with regard to tests other than agglutination tests to be typical B. coli. These microbes (57 and 58) were also agglutinated by the blood both of (*a*) the persons from whose fæces each respective strain of B. coli had been derived and (*b*) of persons whose fæces were not the source of any of the microbes in question. Berne anti-typhoid serum, however, in a dilution of 1 : 200, yielded inconclusive results. Nos. 57 and 58 were used severally to immunise two guinea-pigs, and the specific sera of these rodents were tested against 57 and 58 B. coli, against B. typhosus, and against a large number of B. coli other than 57 and 58. The results are given in a separate table (Table 2), and they may be summarised as follows :—

The specific sera 57 and 58 gave only an incomplete reaction (1 : 20 dilution) with B. typhosus. Serum of microbe 57 agglutinated both B. coli 57 and B. coli 58 to about the same extent, namely, 1 : 200 dilution, gave almost instantaneous result ; 1 : 400 dilution, decided clumping ; 1 : 600 dilution, indication of but incomplete agglutination. Serum of microbe 58 agglutinated both B. coli 57 and 58 to about the same extent, namely, 1 : 800 dilution, complete agglutination ; dilution 1 : 1600, indication of but incomplete clumping.

It should be noted that B. coli 57 and 58 were derived from the same dilution of the same stool, and these microbes were doubtless closely akin. The sera of 57 and 58 B. coli, however, did not agglutinate microbes 55, 56, 59, and 60, which were all isolated from the same stool as B. coli 57 and 58. Neither did their sera agglutinate any of the numerous other strains of B. coli that were tested except coli 51, 52, 53, and 54, and then only in low dilutions.

Serum of 57 B. coli was thus, exclusive of microbes 51, 52, 53, 54, specific only for 57 and 58 coli.

Serum of 58 B. coli was, exclusive of microbes 51, 52, 53, 54, specific only for 58 and 57 coli.

Column 24.—Anti-typhoid Berne serum.

The dilution used was 1 : 200 ; the time of microscopic observation was one hour. The serum tested with B. typhosus gave complete clumping with a dilution of 1 : 500, and nearly complete agglutination with a dilution of 1 : 1000.

Of the 101 B. coli no less than 82 gave a completely negative result.

As regards the remainder, microbes 13, 14, 44, 45, and 47 (possibly also 36, 46, 48, and 35) gave some indication of clumping. Microbes 27, 31, 32, 33, 34, 38, 39, 57, and 58 were practically negative or query negative with regard to clumping. Microbe 41 gave a positive reaction, dilution 1 : 200, and an incompletely positive result, 1 : 800.

Column 25.—Serum of persons supplying the fæces from which B. coli were isolated.

A dilution of 1 : 20 was used, and the time of microscopic observation was one hour.

Of 101 coli-like microbes, 66 yielded completely negative results.

As regards the remainder :—

Microbes 9, 11, 17, 25, 33, 34, 52, 87, and 89 gave only a suspicion of clumping.

Microbes 35, 36, and 41 gave an indication of clumping, but it was incomplete.

44, 46, and 91 yielded practically negative results.

Perhaps all these should be regarded as practically negative, which would alter the figures from 66 to 66 + 15 = 81 (about 80 per cent.).

The remaining microbes fall into the following categories :—

Microbes.

13. Positive 1 : 20, but negative 1 : 80.
14. Positive 1 : 20, but negative 1 : 80.
27. Positive 1 : 20, suspicion of clumping 1 : 80.
28. Positive 1 : 20, suspicion of clumping 1 : 80.
29. Positive 1 : 20, negative 1 : 80.
31. Decided clumping 1 : 20.
32. Fair clumping 1 : 20.
39. Positive 1 : 20, practically negative 1 : 100.
40. Same results as 39.
42. Distinct clumping, 1 in 20.
45. Strongly positive.
47. Fair clumping.
48. Fair clumping.
51. Positive 1 : 20, negative 1 : 100.
57. Positive 1 : 20, indication but incomplete 1 : 100.
58. Positive 1 : 20, indication but incomplete 1 : 100.
83. Fair clumping 1 : 20, negative 1 : 100.
85. Slight clumping 1 : 20.
86. Slight clumping 1 : 20.
88. Fair clumping 1 : 20.

Considering all these as positive it may be said that about 80 per cent. were practically negative and about 20 per cent. positive.

However these results be interpreted, it is obvious that a much larger percentage of the 101 specimens of B. coli were agglutinated definitely with the blood (dilution 1 : 20) of the persons supplying the B. coli from the fæces than were agglutinated with anti-typhoid guinea-pigs' blood (dilution 1 : 20) or anti-typhoid Berne serum (dilution 1 : 200). From this it might be contended that a proportion of the individuals whose stools were tested against their own B. coli were subjects of a kind of coli intoxication. But to this the objection might be made that certain specimens of B. coli are in "negative sympathy," if such a term be permissible, with the blood of human beings in general; that is, that human blood has an inherent property of agglutinating particular strains of fæcal B. coli independently of their origin.

Column 26.—*Serum of persons not supplying fæces from which B. coli of experiment were isolated.*

A dilution of 1 : 20 was used, and the time of microscopic observation was one hour.

Of 101 B. coli, 64 yielded completely negative results.

As regards the remainder :—

Microbes 9, 15, 18, 24, 85, 87, and 90 gave only a suspicion of clumping, and 16 showed only partial clumping.

,, 33, 34, 35, and 36 may, perhaps, be classed as giving an indication of clumping.

,, 39, 46, 51, and 52 were practically negative. Possibly all these should be regarded as practically negative, and if so this would alter the percentage from 64 to 64 + 16 = 80.

The rest fall into the following categories :—

Microbes 13, 14, 17, 27, 28, 29, 31, 32, 57, 58, 75, 77, and 78, positive 1 : 20 ; negative either 1 : 80 or 1 : 100 dilution.

,, 41, 42, and 48, distinct clumping.

,, 45, strongly positive.

,, 47 and 83, fair clumping.

,, 88 and 89, slight clumping.

Considering all these as positive, it may be said that about 80 per cent. were practically negative and about 20 per cent. positive.

These figures are identical with those given in summary of column 25 in the previous paragraph ; and it is important in each case to note whether a given specimen of B. coli yielded positive or negative results alike with (*a*) the serum of the person whose fæces supplied the microbe under investigation and (*b*) with that of an individual not supplying the microbe.

To illustrate this point it will be sufficient to arrange in parallel columns the two series of positive results.

Serum of person supplying B. coli from fæces and causing agglutination of the—	Serum of person *not* supplying B. coli and causing agglutination of the—
Microbe.	Microbe.
13	13
14	14
—	17
27	27
28	28
29	29
31	31
32	32
39	—
40	—
—	41
42	42
45	45
47	47
48	48
51	—
57	57
58	58
—	75
—	77
—	78
83	83
85	—
86	—
88	88
—	89

It is obvious that in nearly all cases each individual specimen of B. coli agglutinated equally well with the sera of the persons whose fæces did *not* supply as with the sera of the persons whose fæces did supply the B. coli. It would thus seem as if certain specimens of B. coli were readily agglutinated with the serum of human blood, independently of the individual supplying the blood. Turning to the cultural characters in various media of those B. coli which yielded positive results, there is found to be no definite or constant indication of these B. coli being in any way different from their neighbours.

This compels the conclusion that ordinary tests may throw into one group coli-like microbes which may subsequently be found to differ conspicuously one from another in their behaviour to different sera. It may, however, be more than mere coincidence that more than half (five out of nine) of the virulent (Column 21, Table 1) B. coli were among the microbes which agglutinated in the presence of certain sera.

Classification of the B. coli derived from normal human fæces.

Two bases of classification may be given, as follows :—

Classification I.

Percentage number of B. coli giving with each separate test the result stated below :—

Cols.	Tests. 1.	Percentage number of B. coli giving with each separate test the result stated in column 1. 2.
1	*Motility*	89
2	"*Gas*" *in gelatine* "*shake*" *cultures*	100
3	*Acid and gas formation, glucose peptone medium*	100
4	*Acid and gas formation, lactose peptone medium*	92
5	[*Cane-sugar peptone medium, negative or atypical results*]	(93)*
6	[*Dulcit peptone medium, acid or bleached appearance, with gas formation*] ...	(55)*
7	*Neutral red broth, greenish-yellow fluorescence*	98
8	*Indol test* (indol in broth cultures)	98
9	*Litmus milk cultures* (*acid and clot*)...	92
10	*Lactose, peptone, sodium carbonate, milk medium* (*gas, acid, and clot*) ...	90
11	*Nitrate broth* (*reduction of nitrates to nitrites*)	100
12	*Proskauer and Capaldi Medium No. I.* (*bright cherry-red colour within 24 hours*).	98
13	*Proskauer and Capaldi Medium No. II.* (*bleached appearance, no definite acidity*).	100
14	*Litmus whey cultures* (28 *to* 46 *per cent.* $\frac{N}{10}$ Na_2CO_3 *to neutralise the acidity*)	96
15	[*Virulence in broth cultures* (*death of rodent within* 48 *hours*)]	(9)*
16	[*No liquefaction of gelatine*]	(100)*
	The growth on potato and agglutination experiments are not included here.	

* The figures are placed in brackets because the corresponding tests stand on a somewhat different footing to the other tests.

Classification II.

Percentage number of B. coli fulfilling all the tests, and number of the microbes that failed in one or more respects; the latter being subdivided into separate groups.

In this classification the cane-sugar and dulcit tests, and tests for pathogenicity, are excluded from consideration.

101 B. coli (normal human fæces)

- 72% *completely* positive, *i.e.*, yielding results as follows:—
  1. Motile.
  2. "Gas" in gelatine shake cultures.
  3. Acid and gas, glucose peptone medium.
  4. " " lactose " "
  5. Positive result, neutral red broth.
  6. " " indol test.
  7. Acid and clot, litmus milk cultures.
  8. Gas acid and clot, lactose peptone milk cultures.
  9. Reduction of nitrates.
  10. Bright cherry-red colour. Proskauer and Capaldi medium, No. I.
  11. Bleached appearance, no definite acidity. Proskauer and Capaldi medium, No. II.
  12. Percentage acidity in litmus whey culture—28 to 46 cc. $\frac{N}{10}$ N_2CO_3.
- 29% not *completely* positive
  - Non-motile, *typical in all other respects.* 11%
  - Non-motile, and atypical in lactose peptone milk medium, *typical in all other respects.* 1%
  - No indol, *typical in all other respects.* 2%
  - Negative result, neutral red broth test, *typical in all other respects.* 2%
  - Atypical lactose peptone milk test, *typical in all other respects.* 1%
  - Atypical litmus milk test, *typical in all other respects.* 4%
  - Atypical lactose, lactose peptone milk, and litmus whey tests, *typical in all other respects.* 3%
  - Atypical lactose, litmus milk, lactose peptone milk, and litmus whey tests, *typical in all other respects.* 2%
  - Atypical lactose, litmus milk, lactose peptone milk, Proskauer and Capaldi (medium No. I.) tests *typical in all other respects.* 3%

It will be noted that as regards 12 tests :—

72 per cent. of the coli were in all respects typical.

29 per cent. failed in one or more respects;

The 29 per cent. comprised 11 per cent. which, although seemingly non-motile, were typical in all other respects.

1 per cent. non-motile and atypical in lactose peptone milk media.

2 per cent. failed as regards indol only.

2 per cent., typical in all other respects, produced no greenish yellow fluorescence in neutral red broth.

1 per cent. atypical only as regards the lactose peptone milk test.

4 per cent. failed only as regards the litmus milk test.

3 per cent. atypical in lactose, lactose peptone milk, and litmus whey cultures.

2 per cent. atypical in lactose, litmus milk, lactose peptone milk, and litmus whey cultures.

3 per cent. atypical in lactose, litmus milk, lactose peptone milk, and Proskauer & Capaldi's (Medium No. I.) cultures.

Of the 29 per cent. not *completely* positive, the majority failed to so slight an extent that they could hardly be classed as atypical B. coli; for example, if the test for *motility* be excluded from consideration, then 83 per cent. of the B. coli were typical.

SECTION II.

Morphological and Biological Characters of 100 B. coli derived from Crude Sewage and 100 B. coli isolated from Sewage Effluents.*

Methods.

The dilutions and primary cultures (in bile-salt glucose peptone medium) were made on the spot immediately after the collection of the sample.

Dilution :

(*a*) 1 c.c. of the sample was added to 9 c.c. of sterile water contained in a test-tube. This dilution was called dilution (1). Each c.c. of the mixture represented ·1 c.c. of the sample.

(*b*) 1 c.c. of dilution (1) was added to another tube containing 9 c.c. of sterile water. This dilution was called dilution (2). Each c.c. of the mixture represented ·01 c.c. of the sample.

(*c*) 1 c.c. of dilution (2) was added to another tube containing 9 c.c. of sterile water. This dilution was called dilution (3). Each c.c. of the mixture represented ·001 c.c. of the sample.

(*d*) 1 c.c. of dilution (3) was added to another tube containing 9 c.c. of sterile water. This dilution was called dilution (4). Each c.c. of the mixture represented ·0001 c.c. of the sample.

(e) 1 c.c. of dilution (4) was added to another tube containing 9 c.c. of sterile water. This dilution was called dilution (5). Each c.c. of the mixture represented ·00001 c.c. of the sample.

(f) 1 c.c. of dilution (5) was added to another tube containing 9 c.c. of sterile water. This dilution was called dilution (6). Each c.c. of the mixture represented ·000001 c.c. of the sample.

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* The effluents were not all final effluents, and some precipitation liquors are included under this heading.

(g) 1 c.c. of dilution (6) was added to another tube containing 9 c.c. of sterile water. This dilution was called dilution (7). Each c.c. of the mixture represented ·0000001 c.c. of the sample.

(h) 1 c.c. of dilution (7) was added to another tube containing 9 c.c. of sterile water. This dilution was called dilution (8). Each c.c. of the mixture represented ·00000001 c.c. of the sample.

The amount of sewage or effluent in 1 c.c. of each of the above dilutions is shown in the following table :—

Dilution.	Each c.c. represents the following fractions of a cubic centimetre of the sample : –		To obtain results per c.c. of sample multiply results by :—
(1)	$\frac{1}{10}$	·1	10
(2)	$\frac{1}{100}$	·01	100
(3)	$\frac{1}{1000}$	·001	1,000
(4)	$\frac{1}{10000}$	·0001	10,000
(5)	$\frac{1}{100000}$	·00001	100,000
(6)	$\frac{1}{1000000}$	·000001	1,000,000
(7)	$\frac{1}{10000000}$	·0000001	10,000,000
(8)	$\frac{1}{100000000}$	·00000001	100,000,000

Primary bile-salt glucose peptone cultures were made from the various dilutions, 1 c.c. being used in each instance. After incubation at 37° C. for two days surface gelatine plate cultures from the primary cultures were made. On the second day they were examined, and the subsequent procedure was exactly as described under "methods" in the previous section. That is, two typical-looking B. coli were subcultured from the last three plates from the last three dilutions showing the presence of B. coli.

The tests employed differed in some respects from those used in the examination of the fæces. They may be summed up as follows :—*

Motility.

Gelatine "shake" cultures, for gas formation.

Glucose peptone cultures *Lactose peptone cultures* *Dulcit peptone cultures* *Cane-sugar peptone cultures* *Mannite peptone cultures* *Raffinose peptone cultures* *Salicin peptone cultures* *Inulin peptone cultures*	For observation as regards gas formation.

Broth cultures, for indol formation.

Litmus milk cultures, for acid clothing of the medium.

Neutral-red broth cultures, for greenish yellow fluorescence.

The results are given in Tables 3 and 4.

* I am greatly indebted to Miss Chick and Miss Hartley for their valuable assistance during this investigation.

Analysis of the Results.

Dealing with the various columns *seriatim* :—

Column 1. *Identification number of B. coli.* No comment is needed here.

Column 2. *Source of Sewages and Effluents.*

Sewages.	*Effluents* (including some precipitation liquors).
Hendon	Ducat filter effluent at Hendon (continuous filtration process).
Ealing	Ealing effluent (lime and alumino-ferric precipitation and one contact bed).
Ilford	Croydon (S. Norwood) effluent (land treatment).
Hampton	Ilford effluent (lime and "copperas" precipitation liquor).
Kingston	Barking effluent (lime and protosulphate of iron precipitation liquor).
Caterham Barracks	Hampton effluent (three contact beds, but first two practically worked as "streaming" filters).
Croydon (Beddington)	Kingston effluent (A.B.C. precipitation liquor).
Sutton	Croydon (Beddington) effluent (land treatment).
Barking	Barking effluent (precipitation and one contact bed).
Maidstone	Aldershot Camp effluent (land treatment).
Guildford	Newton-le-Willows effluent (one contact bed).
Godalming	Manchester effluent (open septic tank and one contact bed).
Leeds	Oswestry effluent (settling tank and two contact beds).
Normanton	Liverpool Fever Hospital (at Fazakerley) effluent (closed septic tank and two contact bed effluents).
St. Albans	Accrington effluent (open septic tank and continuous filtration process).
Aldershot Camp	Leeds effluent (closed septic tank and one contact-bed).
Croydon (S. Norwood)	Shipley effluent (settlement and two contact beds).

With the following exceptions the sewages may be regarded as domestic (or nearly so)* :—

Normanton sewage contains a good deal of slop water.

Hendon sewage (much laundry refuse)
Kingston sewage (a little brewery refuse)
Ilford sewage (washings from photographic works)
Oswestry sewage (cattle market and a little brewery refuse)
Godalming sewage (tannery refuse)
} Domestic mixed with a small proportion of trade waste.

Barking sewage
Maidstone sewage
Guildford sewage
Leeds sewage
Manchester sewage
Oswestry sewage
Shipley sewage
} Mixed with trade refuse.

Fazakerley sewage is an example of a Fever Hospital (Liverpool) sewage.

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* I am indebted to the notes of my colleagues, Dr. McGowan, Mr. Frye, and Mr. Kershaw, for the foregoing classification.

Column 3. $\frac{\text{L. D.}}{1}$; $\frac{\text{L. D.}}{10}$; $\frac{\text{L. D.}}{100}$

By $\frac{\text{L. D.}}{1}$ is meant the last dilution of the sample yielding B. coli, $\frac{\text{L. D.}}{10}$ represents the dilution ten times lower, and $\frac{\text{L. D.}}{100}$ the dilution one hundred times lower in the scale of dilutions. Thus, two microbes from each of the last three dilutions yielding B. coli in each of the 17 samples were selected for examination.* The dilutions were made in successive tenths, *i.e.*, by the decimal mode of dilution.

SEWAGES.	EFFLUENTS.

Column 4.—The 100 specimens of B. coli were isolated respectively from :—

(Derived respectively from 17 different sources.)

Sewages		Effluents	
c.c.		c.c.	
1/1,000,000,	sixteen per cent.	1/1,000,000,	two per cent.
1/100,000,	twenty-eight per cent.	1/100,000,	sixteen per cent.
1/10,000,	thirty-four per cent.	1/10,000,	twenty-two per cent.
1/1,000,	eighteen per cent.	1/1,000,	thirty per cent.
1/100,	four per cent.	1/100,	eighteen per cent.
		1/10,	twelve per cent.

Column 5.—*Motility.*

Sewages		Effluents	
Motile	71 per cent.	Motile	79 per cent.
Non-motile or not observed to be motile	29 per cent.	Non-motile or not observed to be motile	21 per cent.

Column 6.—"*Gas*" *in ordinary gelatine* "*shake*" *cultures* (24 *hours at* 20° C.).

Sewages	Effluents
Positive result, 100 per cent.	Positive result, 100 per cent.

Column 7.—*Gas formation in glucose peptone medium* (2 *days at* 37° C.).

Sewages	Effluents
Positive result, 96 per cent.	Positive result, 98 per cent.
Slight gas formation, 4 per cent.	Slight gas formation, 1 per cent.
	Negative result, 1 per cent.

Column 8.—*Gas formation in lactose peptone medium* (2 *days at* 37° C.).

Sewages	Effluents
Positive result, 94 per cent.	Positive result, 92 per cent.
Negative result, 6 per cent.	Slight gas formation, 4 per cent.
	Negative result, 4 per cent.

Column 9.—*Gas formation in cane-sugar peptone medium* (2 *days at* 37° C.).

Sewages	Effluents
Positive result, 29 per cent.	Positive result, 32 per cent.
Slight gas formation, 3 per cent.	Slight gas formation, 5 per cent.
Negative result, 68 per cent.	Negative result, 62 per cent.
	No record, 1 per cent.

Column 10.—*Gas formation in dulcit peptone medium* (2 *days at* 37° C.).

Sewages	Effluents
Positive result, 34 per cent.	Positive result, 44 per cent.
Slight gas formation, 4 per cent.	Slight gas formation, 5 per cent.
Traces of gas, 1 per cent.	Traces of gas, 1 per cent.
Negative result, 61 per cent.	? no gas, 1 per cent.
	Negative result, 49 per cent.

* As regards the 17th sample of sewage and of effluent, two B. coli from the last two (instead of the last three) dilutions were selected for examination so as to bring the total number of B. coli up to exactly 100.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Descriptive number of B. coli.	Source of Sewage.	Dilution. LD, LD/10, LD/100. See text.	Isolated from	Motility. + = motile; ? – = not observed to be motile.	Gas in ordinary gelatine shake culture. + = gas. 24 hours at 20° C.	Glucose, 1%; peptone, 2%; litmus medium. + = gas formation, 2 days at 37° C.	Lactose, 1%; peptone, 2%; litmus medium. + = gas formation, 2 days at 37° C.	Cane Sugar, 1%; peptone, 2%; litmus medium. + = gas formation, 2 days at 37° C.	Dulcite, 1%; peptone, 2%; litmus medium. + = gas formation, 2 days at 37° C.	Mannite, 1%; peptone, 2%; litmus medium. + = gas formation, 2 days at 37° C.	Raffinose, 0·5%; peptone, 1%; litmus medium. + = gas formation, 2 days at 37° C.	Salicin, 0·5%; peptone, 1%; litmus medium. + = gas formation, 2 days at 37° C.	Inulin, 0·5%; peptone, 1%; litmus medium. + = gas formation, 2 days at 37° C.	Neutral red broth medium. + = greenish-yellow fluorescence, 2 days at 37° C.	Indol in broth culture. + = indol, 5 days at 37° C.	Litmus milk culture. + = acid clot, 5 days at 37° C.	Liquefaction of gelatine. 0 = no liquefaction, 30 days at 20° C.
1	Hendon	LD/100	1/10,000 c.c.	? –	+	+	+	–	–	+	–	+	–	+	+	+	0
2	„	„	„	+	+	+	+	sl. gas	–	+	sl. gas	–	–	+	+	+	0
3	„	LD/10	1/100,000	+	+	+	+	–	–	+	–	sl. gas	–	+	+	+	0
4	„	„	„	+	+	+	+	–	–	+	–	tr. gas	–	+	+	+	0
5	„	LD/1	1/1,000,000	+	+	+	+	–	+	+	–	tr. gas	–	+	+	+	0
6	„	„	„	+	+	+	+	–	+	+	–	tr. gas	–	+	+	+	0
7	Ealing	LD/100	1/10,000	+	+	+	+	–	–	+	–	–	–	+	+	+	0
8	„	„	„	? –	+	+	+	–	+	+	–	sl. gas	–	+	–	+	0
9	„	LD/10	1/100,000	? –	+	+	+	–	–	+	–	–	–	+	+	+	0
10	„	„	„	? –	+	+	+	–	–	+	–	–	–	+	+	+	0
11	„	LD/1	1/1,000,000	? –	+	+	+	–	–	+	–	+	–	+	+	+	0
12	„	„	„	+	+	+	+	–	–	+	–	+	–	+	+	+	0
13	Ilford	LD/100	1/10,000	+	+	+	+	–	+	+	–	+	–	+	+	+	0
14	„	„	„	? –	+	+	+	+	–	+	tr. gas	+	–	+	+	+	0
15	„	LD/10	1/100,000	+	+	+	+	sl. gas	+	+	tr. gas	–	–	+	+	+	0
16	„	„	„	+	+	+	+	+	+	+	tr. gas	–	–	+	+	+	0
17	„	LD/1	1/1,000,000	+	+	+	+	+	+	+	tr. gas	–	–	+	+	+	0
18	„	„	„	? –	+	+	+	+	–	+	+	+	–	+	–	+	0
19	Hampton	LD/100	1/1,000	+	+	+	+	–	sl. gas	+	–	sl. gas	–	+	+	+	0
20	„	„	„	+	+	+	+	–	–	+	–	–	–	+	+	+	0
21	„	LD/10	1/10,000	+	+	+	+	–	sl. gas	+	–	tr. gas	–	+	+	+	0
22	„	„	„	+	+	+	+	–	–	+	–	+	–	+	+	+	0
23	„	LD/1	1/100,000	+	+	+	+	–	–	+	–	+	–	+	+	+	0
24	„	„	„	+	+	+	+	–	–	+	–	+	–	+	+	+	0
25	Kingston	LD/100	1/1,000	+	+	+	+	+	+	+	sl. gas	+	–	+	+	+	0
26	„	„	„	+	+	+	+	+	+	+	+	+	–	+	+	+	0
27	„	LD/10	1/10,000	+	+	+	+	–	tr. gas	+	–	+	–	+	+	+	0
28	„	„	„	+	+	+	+	–	+	+	–	+	–	+	+	+	0
29	„	LD/1	1/100,000	+	+	+	+	–	–	+	–	–	–	+	+	+	0
30	„	„	„	+	+	+	+	–	–	+	–	sl. gas	–	+	+	+	0
31	Caterham	LD/100	1/100	+	+	+	+	–	–	+	–	–	–	+	+	+	0
32	„	„	„	+	+	+	+	+	+	+	tr. gas	–	–	+	+	+	0
33	„	LD/10	1/1,000	+	+	+	+	+	–	+	tr. gas	–	–	+	+	+	0
34	„	„	„	+	+	+	+	+	–	+	tr. gas	tr. gas	–	+	+	+	0
35	„	LD/1	1/10,000	+	+	+	+	+	–	+	tr. gas	–	–	+	+	+	0
36	„	„	„	+	+	+	+	+	–	+	tr. gas	tr. gas	–	+	+	+	0
37	Croydon (Beddington)	LD/100	1/1,000	? –	+	+	+	+	–	+	sl. gas	–	–	+	+	+	0
38	„ „	„	„	+	+	+	+	–	+	+	–	–	–	+	+	+	0
39	„ „	LD/10	1/10,000	? –	+	+	+	–	+	+	–	–	–	+	–	+	0
40	„ „	„	„	+	+	+	+	–	–	+	–	–	–	+	+	+	0
41	„ „	LD/1	1/100,000	? –	+	+	+	–	+	+	–	–	–	+	+	+	0
42	„ „	„	„	+	+	+	+	+	+	+	tr. gas	tr. gas	–	+	+	+	0
43	Sutton	LD/100	1/1,000	? –	+	+	+	–	–	+	–	–	–	+	+	+	0
44	„	„	„	? –	+	+	+	–	–	+	–	–	–	+	+	+	0
45	„	LD/10	1/10,000	? –	+	+	+	–	–	+	–	–	–	+	+	+	0
46	„	„	„	? –	+	+	+	–	–	+	–	–	–	+	+	+	0
47	„	LD/1	1/100,000	? –	+	+	+	–	–	+	–	–	–	+	+	+	0
48	„	„	„	+	+	+	+	+	+	+	tr. gas	tr. gas	–	+	+	+	0
49	Barking	LD/100	1/10,000	+	+	+	+	+	+	+	tr. gas	–	–	+	+	+	0
50	„	„	„	+	+	+	+	+	–	+	tr. gas	–	–	+	+	+	0
51	„	LD/10	1/100,000	+	+	+	+	–	–	+	–	tr. gas	–	+	+	+	0
52	„	„	„	+	+	+	+	–	–	+	–	sl. gas	–	+	+	+	0
53	„	LD/1	1/1,000,000	+	+	+	+	+	–	+	–	–	–	+	–	–	0
54	„	„	„	+	+	+	+	+	–	+	–	–	–	? –	–	–	0
55	Maidstone	LD/100	1/1,000	+	+	+	+	+	sl. gas	+	tr. gas	tr. gas	–	+	+	+	0
56	„	„	„	+	+	+	+	+	+	+	tr. gas	–	–	+	+	+	0
57	„	LD/10	1/10,000	+	+	+	+	–	+	+	–	–	–	+	+	+	0
58	„	„	„	? –	+	+	+	–	+	+	–	+	–	+	+	+	0
59	„	LD/1	1/100,000	? –	+	+	+	–	–	+	–	tr. gas	–	+	+	+	0
60	„	„	„	+	+	+	+	–	–	+	–	tr. gas	–	+	+	+	0
61	Guildford	LD/100	1/1,000	+	+	+	+	+	+	+	sl. gas	+	–	+	+	+	0
62	„	„	„	+	+	+	+	+	+	+	+	+	–	+	+	+	0
63	„	LD/10	1/10,000	+	+	+	+	–	+	+	–	+	–	+	+	+	0
64	„	„	„	+	+	+	+	–	+	+	–	+	–	+	+	+	0
65	„	LD/1	1/100,000	+	+	+	+	–	–	+	–	+	–	+	+	+	0
66	„	„	„	? –	+	+	+	sl. gas	–	+	+	–	–	+	+	+	0
67	Godalming	LD/100	1/100	? –	+	+	+	–	sl. gas	+	sl. gas	+	–	+	+	+	0
68	„	„	„	+	+	+	+	–	+	+		–	–	+	+	+	0
69	„	LD/10	1/1,000	+	+	+	+	–	+	+	–	–	–	+	+	+	0
70	„	„	„	+	+	+	+	[illegible]	[illegible]	+	–	+	–	+	+	+	0
71	„	LD/1	1/10,000	+	+	+	+	–	–	+	–	+	–	+	+	+	0
72	„	„	„	+	+	+	+	–	+	+	–	–	–	+	+	+	0
73	Leeds	LD/100	1/10,000	? –	+	+	+	–	–	+	–	–	–	+	+	+	0
74	„	„	„	? –	+	+	+	+	+	+	+	+	–	+	+	+	0
75	„	LD/10	1/100,000	+	+	sl. gas	–	–	–	sl. gas	–	sl. gas	–	–	–	–	0
76	„	„	„	? –	+	sl. gas	–	–	–	sl. gas	sl. gas	tr. gas	–	–	–	–	0
77	„	LD/1	1/1,000,000	? –	+	sl. gas	–		–	sl. gas	tr. gas	tr. gas	–	–	–	–	0
78	„	„	„	? –	+	sl. gas	–	–	–	sl. gas	tr. gas	tr. gas	–	–	–	–	0
79	Normanton	LD/100	1/10,000	+	+	+	+	–	–	+	–	+	–	+	+	+	0
80	„	„	„	? –	+	+	+	–	–	+	–	–	–	+	+	+	0
81	„	LD/10	1/100,000	+	+	+	+	+	+	+	sl. gas	+	–	+	–	+	0
82	„	„	„	+	+	+	+	+	+	+	sl. gas	–	–	+	–	+	6
83	„	LD/1	1/1,000,000	+	+	+	–	+	–	+	–	–	–	+	–	–	sl. liq.
84	„	„	„	+	+	+	–	+	–	+	–	–	–	+	–	–	sl. liq.
85	St. Albans	LD/100	1/10,000	? –	+	+	+	–	–	+	–	tr. gas	–	+	+	+	0
86	„	„	„	+	+	+	+	–	+	+	–	+	–	+	+	+	0
87	„	LD/10	1/100,000	? –	+	+	+	+	–	+	sl. gas	+	–	+	+	+	0
88	„	„	„	+	+	+	+	+	+	+	–	–	–	+	+	+	0
89	„	LD/1	1/1,000,000	+	+	+	+	–	–	+	–	sl. gas	–	+	+	+	0
90	„	„	„	+	+	+	+	–	–	+	–	+	–	+	+	+	0
91	Aldershot Camp	LD/100	1/10,000	+	+	+	+	–	–	+	–	–	–	+	+	+	0
92	„ „	„	„	? –	+	+	+	–	–	+	–	+	–	+	+	+	0
93	„ „	LD/10	1/100,000	+	+	+	+	–	–	+	–	sl. gas	–	+	+	+	0
94	„ „	„	„	+	+	+	+	–	–	+	–	sl. gas	–	+	+	+	0
95	„ „	LD/1	1/1,000,000	? –	+	+	+	–	–	+	–	–	–	+	+	+	0
96	„ „	„	„	+	+	+	+	–	–	+	–	–	–	+	+	+	0
97	Croydon (S. Norwood)	LD/10	1/1,000	+	+	+	+	–	–	+	–	+	–	+	+	+	0
98	„	„	„	+	+	+	+	–	–	+	–	+	–	+	+	+	0
99	„	LD/1	1/10,000	+	+	+	+	–	+	+	–	+	–	+	+	+	0
100	„	„	„	+	+	+	+	–	–	+	–	+	–	+	+	+	0

TABLE 4.—SHOWING THE BIOLOGICAL CHARACTERS OF 100 B. COLI ISOLATED FROM EFFLUENTS.

1. Descriptive number of B. coli.	2. Source of Effluent.	3. Dilution, LD, LD/1, 10, 100. See text.	4. Isolated from—	5. Motility. + = motile; – = not observed to be motile.	6. Gas in gelatine "shake" cultures. + = gas. 24 hours at 20° C.	7. Glucose, 1% peptone, 2% litmus medium. + = gas formation, 2 days at 37° C.	8. Lactose, 1% peptone, 2% litmus medium. + = gas formation, 2 days at 37° C.	9. Cane Sugar, 1% peptone, 2% litmus medium. + = gas formation, 2 days at 37° C.	10. Dulcit, 1% peptone, 2% litmus medium. + = gas formation, 2 days at 37° C.	11. Mannite, 1% peptone, 2% litmus medium. + = gas formation, 2 days at 37° C.	12. Raffinose, 0.5% peptone, 1% litmus medium. + = gas formation, 2 days at 37° C.	13. Salicin, 0.5% peptone, 1% litmus medium. + = gas formation, 2 days at 37° C.	14. Inulin, 0.5% peptone, 1% litmus medium. + = gas formation, 2 days at 37° C.	15. Neutral red broth cultures. + = greenish yellow fluorescence, 2 days at 37° C.	16. Indol in broth cultures. + = indol, 5 days at 37° C.	17. Litmus milk cultures. + = acid and clot, 5 days at 37° C.	18. Liquefaction of gelatine. 0 = no liquefaction. 30 days at 20° C.
1	Ducat filter process (Hendon).	LD/100	1/10	? –	+	+	+	–	–	+		sl. gas	–	+	+	+	0
2	"	"	"	? –	+	+	+	–	–	+	–	+	–	+	+	+	0
3	"	LD/10	1/100	+	+	+	+	–	+	+	–	–	–	+	+	+	0
4	"	"	"	+	+	+	+	–	tr. gas	+	–	+	–	+	+	+	0
5	"	LD/1	1/1,000	+	+	+	+	–	–	+	–	sl. gas	–	+	+	–	0
6	"	"	"	+	+	+	+	–	–	+	–	+		+	+	+	0
7	Ealing Effluent (precipitation and one contact).	LD/100	1/1,000	+	+	+	+	–	–	+	–	–	–	? –	+	+	0
8	"	"	"	+	+	+	+	–	–	+	–	–	–	? –	+	+	0
9	"	LD/10	1/10,000	+	+	+	+	–	+	+	–	sl. gas	–	+	+	+	0
10	"	"	"	+	+	+	+	–	–	+	–	+	–	+	+	+	0
11	"	LD/1	1/100,000	? –	+	+	+	–	–	+	–	–	–	+	+	+	0
12	"	"	"	+	+	+	+	–	–	+	–	tr. gas	–	+	+	+	0
13	Croydon, S. Norwood (Land Effluent).	LD/100	1/10	+	+	+	+	–	–	+	–	–	–	+	+	+	0
14	"	"	"	+	+	+	+	–	–	+	–	tr. gas	–	+	–	+	0
15	"	LD/10	1/100	? –	+	+	+	sl. gas	+	+	–	–	–	+	–	+	0
16	"	"	"	+	+	+	+	–	sl. gas	+	+	–	–	+	+	+	0
17	"	LD/1	1/1,000	+	+	+	+	+	+	+	–	–	–	? –	–	–	0
18	"	"	"	+	+	+	+	+	+	+	–	–	–	+	–	–	0
19	Ilford precipitation liquor.	LD/100	1/100	+	+	+	+	–	+	+	–	–	–	+	+	+	0
20	"	"	"	? –	+	+	+	–	+	+	–	tr. gas	–	+	+	+	0
21	"	LD/10	1/1,000	? –	+	+	+	–	–	+	–	tr. gas		+	+	+	0
22	"	"	"	+	+	+	+	–	+	+		–	–	+	+	+	0
23	"	LD/1	1/10,000	+	+	+	+	–	–	+	+	–	–	+	+	+	0
24	"	"	"	+	+	+	+	–	–	+	+	tr. gas		+	+	+	0
25	Barking precipitation liquor.	LD/100	1/1,000	? –	+	+	+	+	+	+	+	--			+		0
26	"	"	"	? –	+	+	+	–	+	+	–	–	–	+	+	+	0
27	"	LD/10	1/10,000	+	+	+	+	+	–	+	–	tr. gas	–	+	–	–	0
28	"	"	"	? –	+	+	+	+	+	+	+	–	–	–	+	–	0
29	"	LD/1	1/100,000	+	+	+	+	–	–	+	tr. gas			+	+	+	0
30	"	"	"	+	+	+	+	–	? –	+	sl. gas	tr. gas	–	+	+	+	0
31	Hampton final effluent (contact bed process).	LD/100	1/100	? –	+	+	+	sl. gas	+	+	tr. gas	–	–	+	+	+	0
32	"	"	"	+	+	+	+	–	–	+	–	sl. gas	–	+	+	+	0
33	"	LD/10	1/1,000	+	+	+	+	+	+	+	tr. gas	sl. gas	–	+	+	+	0
34	"	"	"	+	+	+	+	+	+	+	tr. gas	+	–	+	+	+	0
35	"	LD/1	1/10,000	+	+	+	+	–	–	+	–	–	–	+	+	+	0
36	"	"	"	+	+	+	+	–	–	+	–		–	+	+	+	0
37	Kingston precipitation liquor.	LD/100	1/10	+	+	+	+	–	+	+	–	–	–	+	+	+	0
38	"	"	"	? –	+	+	+	–	–	+	–	–	–	+	+	+	0
39	"	LD/10	1/100	+	+	+	+	+	+	+	+	sl. gas	–	–		+	sl. liq.
40	"	"	"	+	+	+	+	–	+	+	–	–	–	+	+	+	0
41	"	LD/1	1/1,000	+	+	+	+	+	+	+	tr. gas	tr. gas	–	+	+	+	0
42	"	"	"	+	+	+	+	+	sl. gas	+	tr. gas	–	–	+	+	+	0
43	Croydon, Beddington land effluent.	LD/100	1/10	? –	+	+	+	–	–	+	–	+	–	+	+	+	0
44	"	"	"	+	+	+	+	+	+	+	+	–	–	+	+	+	0
45	"	LD/10	1/100	+	+	+	+	–	+	+	+	tr. gas	–	+	+	+	0
46	"	"	"	+	+	+	+	–	+	+	+	tr. gas	–	+	–	+	0
47	"	LD/1	1/1,000	+	+	+	+	–	–	+	+	–	–	+	+	+	0
48	"	"	"	+	+	+	+	–	–	+	+	tr. gas	–	+	+	+	0
49	Barking, contact bed effluent.	LD/100	1/1,000	+	+	+	+	+	+	+	tr. gas	–	–	+	–	+	0
50	"	"	"	+	+	+	sl. gas	–	+	+	tr. gas	–	–	+	–	+	0
51	"	LD/10	1/10,000	+	+	+	+	–	+	+	–	–	–	+	+	+	0
52	"	"	"	+	+	+	+	–	+	+	–	–	–	+	+	+	0
53	"	LD/1	1/100,000	+	+	+	+	No record.	–	+	tr. gas	tr. gas	–	+	–	–	0
54	"	"	"	+	+	+	sl. gas	+	–	+	tr. gas	tr. gas	–	+	–	–	0
55	Aldershot Camp, land effluent.	LD/100	1/10	+	+	+	+	–	+	+	–	+	–	+	+	+	0
56	"	"	"	+	+	+	+	–	+	+	–	–	–	+	+	+	0
57	"	LD/10	1/100	+	+	+	+	–	+	+	–	–	–	+	+	+	0
58	"	"	"	+	+	+	+	–	+	+	–	–	–	+	+	+	0
59	"	LD/1	1/1,000	+	+	+	+	–	–	+	–	+	–	+	+	+	0
60	"	"	"	+	+	+	+	–	–	+	–	sl. gas	–	+	+	+	0
61	Newton-le-Willows, contact bed effluent.	LD/100	1/1,000	+	+	+	+	–	–	+	–	+	–	+	+	+	0
62	"	"	"	+	+	+	+	–	+	+	–	sl. gas	–	+	+	+	0
63	"	LD/10	1/10,000	+	+	+	+	–	sl. gas	+	–	sl. gas	–	+	+	+	0
64	"	"	"	+	+	+	+	+	sl. gas	+	–	–	–	+	+	+	0
65	"	LD/1	1/100,000	+	+	+	+	+	–	+	–	–	–	+	–	+	0
66	"	"	"	+	+	+	+	+	–	+	–	–	–	+	–	+	0
67	Manchester, contact bed effluent.	LD/100	1/10,000	+	+	+	–	+	sl. gas	+	–	–	–	+	–		0
68	"	"	"	+	+	+	–	+	–	+	+	sl. gas	–	–	–	–	0
69	"	LD/10	1/100,000	+	+	+	+	+	–	+	+	+	–	–	+	+	0
70	"	"	"	+	+	+	+	+	–	+	sl. gas	tr. gas	–	–	+	–	0
71	"	LD/1	1/[illegible]	+	+	+	sl. gas	+	–	+	sl. gas	+	–	–	–	–	0
72	"	"	"	+	+	+	+	+	–	+	sl. gas	+	–	–		–	0
73	Oswestry, 2nd contact bed effluent	LD/100	1/1,000	+	+	+	+	+	+	+	–	–	–	+	+	+	0
74	"	"	"	? –	+	+	+	–	+	+	–	–	–	+	+	+	0
75	"	LD/10	1/10,000	+	+	+	+	–	+	+	–	+	–	+	+	+	0
76	"	"	"	–	+	+	+	–	–	+	–	+	–	+	+	+	0
77	"	LD/1	1/100,000	–	+	+	+	–	–	+	–	+	–	? –	+	+	0
78	"	"	"	? –	+	+	+	–	–	+	–	+	–	+	+	+	0
79	Liverpool Fever Hospital, at Fazakerley (septic tank and two contact beds).	LD/100	1/10	+	+	+	+	–	–	+	–	–	–	+	+	+	0
80	"	"	"	+	+	+	+	–	+	+		+	–	+	+	+	0
81	"	LD/10	1/100	+	+	+	+	–	–	+	–	–	–	+	–	+	0
82	"	"	"	+	+	+	+	–	–	+	–	–	–	+	–	+	0
83	"	LD/1	1/1,000	+	+	+	+	–	–	+	–	–	–	+	–	–	0
84	"	"	"	+	+	+	+	–	–	+	–	–	–	+	–	–	0
85	Accrington, effluent (septic tank and continuous filtration).	LD/100	1/100	+	+	+	+	sl. gas	+	+	–	tr. gas	–	+	+	+	0
86	"	"	"	? –	+	+	+	–	+	+	–	–	–	+	–	+	0
87	"	LD/10	1/1,000	+	+	+	–	+	+	+	–	–	–	+	–	–	0
88	"	"	"	+	+	+	–	+	+	+	–	–	–	+	–	–	0
89	"	LD/1	1/10,000	+	+	+	+	+	–	+	+	+	–	–	–	–	0
90	"	"	"	+	+	+	+	+	–	+	+	+	–	–	–	–	0
91	Leeds, effluent (septic tank and one contact bed).	LD/100	1/1,000	+	+	+	+	+	+	+	–	tr. gas	–	+	+	+	0
92	"	"	"	+	+	+	+	–	+	+	–	tr. gas	–	+	+	+	0
93	"	LD/10	1/10,000	+	+	+	sl. gas	+	–	+	–	–	–	+	–	–	0
94	"	"	"	+	+	+	+	+	–	+	tr. gas	–	–	+	–	+	0
95	"	LD/1	1/100,000	? –	+	sl. gas	+	+	–	+	–	tr. gas	–	–	–	+	0
96	"	"	"	? –	+	–	+	+	–	+	–	+	–	–	–	+	0
97	Shipley, effluent (two contact beds).	LD/10	1/10,000	+	+	+	+	–	+	+	–	+	–	+	+	+	0
98	"	"	"	+	+	+	+	–	+	+	–	+	–	+	+	+	0
99	"	LD/1	1/100,000	? –	+	+	+	sl. gas	+	+	–	–	–	? –	+	+	0
100	"	"	"	? –	+	+	+	sl. gas	+	+	–	–	–	+	+	+	0

SEWAGES.	EFFLUENTS.

Column 11.—*Gas formation in Mannite peptone medium* (2 *days at* 37° C.).

Positive result, 96 per cent.	Positive result, 100 per cent.
Slight gas formation, 4 per cent.	

Column 12.—*Gas formation in Raffinose peptone medium* (2 *days at* 37° C.).*

Positive result, 5 per cent.	Positive result, 15 per cent.
Slight gas formation, 9 per cent	Slight gas formation, 4 per cent.
Traces of gas, 17 per cent.	Traces of gas, 11 per cent.
Negative result, 69 per cent.	Negative result, 70 per cent.

Column 13.—*Gas formation in Salicin peptone medium* (2 *days at* 37° C.).*

Positive result, 33 per cent.	Positive result, 22 per cent.
Slight gas formation, 9 per cent.	Slight gas formation, 10 per cent.
Traces of gas, 16 per cent.	Traces of gas, 18 per cent.
Negative result, 42 per cent.	Negative result, 50 per cent.

Column 14.—*Gas formation in inulin peptone medium* (2 *days at* 37° C.)

Negative result, 100 per cent.	Negative result, 100 per cent.

Column 15.—*Greenish-yellow fluorescence in neutral red broth cultures* (2 *days at* 37° C.).

Positive result, 95 per cent.	Positive result, 83 per cent.
? Negative result, 1 per cent.	? Negative result, 5 per cent.
Negative result, 4 per cent.	Negative result, 12 per cent.

Column 16.—*Indol in broth cultures* (5 *days at* 37° C.).

Positive result, 85 per cent.	Positive result, 70 per cent.
Negative result, 15 per cent.	Negative result, 30 per cent.

Column 17.—*Acid clot in litmus milk cultures* (5 *days at* 37° C.).†

Positive result, 92 per cent.	Positive result, 80 per cent.
Negative result, 8 per cent.	Negative result, 20 per cent.

Column 18.—*Liquefaction of gelatine* (30 *days at* 20° C.).

No liquefaction, 98 per cent.	No liquefaction, 99 per cent.
Slow liquefaction, 2 per cent.	Slow liquefaction, 1 per cent.

---

* Dr. Gordon has found some of these tests (*e g.*, raffinose and salicin) of value in the differentiation of streptococci. They serve here to indicate that some races of B. coli, which seem identical when examined by the ordinary tests, may be shown by amplifying the number and kind of tests to present certain points of difference. How far it is desirable to consider these differences as indicating a difference of species among the B. coli group of microbe is a difficult question.

† In the Chichester inquiry of the well-water B. coli, only 76, 28, and 38 per cent. yielded positive results with the neutral red broth, indol, and litmus milk tests respectively. (*See* page 547, App. B., No. 5, Report of the Medical Officer, Local Gov. Board, 1902–3.)

Classification of the B. coli derived from the sewages and effluents.

Classification I.

Percentage number of B. coli giving with each separate test the results stated below :—

Tests. [For the sake of simplicity *feebly* positive and *atypical* results are recorded as negative.*]	Percentage number of B. coli giving with each separate test the result stated in column 1.	
Cols. 1.	2.	3.
	Sewage, Per cent.	Effluents, Per cent.
1. Motility - - - - - - - - - -	71	79
2 Gas in gelatine "shake" cultures - - - - - -	100	100
3. Gas formation in glucose peptone cultures - - -	96	98
4. Gas formation in lactose peptone cultures - - - -	94	92
5. Gas formation in cane-sugar peptone cultures - - -	29	32
6. Gas formation in dulcit peptone cultures - - - -	34	44
7. Gas formation in mannite peptone cultures - - - -	96	100
8. Gas formation in raffinose peptone cultures - - - -	5	15
9. Gas formation in salicin peptone cultures - - - -	33	22
10. Gas formation in inulin peptone cultures - - - -	none	none
11. Greenish-yellow fluorescence in neutral red broth cultures -	95	83
12. Indol in broth cultures - - - - - - - -	85	70
13. Acid clot in litmus milk cultures - - - - - -	92	80
14. No liquefaction of gelatine - - - - - - -	98	99

Classification II.

Percentage number of B. coli fulfilling all the tests, and number of those microbes that failed in one or more respects; the latter being subdivided into separate groups.

In this classification the cane-sugar, dulcit, mannite, raffinose, salicin, and inulin tests are excluded from consideration. Moreover, as regards the other tests, atypical or doubtfully positive results are recorded as negative.

* It is obvious, however, that the percentage figures will vary greatly according to whether feebly positive and atypical results be recorded as positive or negative. As the results are given in detail in Tables 3 and 4, the reader may interpret them in whatever way seems best.

The results as regards the sewages are shown in the following diagram :—

100 B. coli (sewage).

- 37 % not *completely* positive.
  - *Non-motile*, typical in all other respects. 22%
  - *Non-motile, no indol*, typical in all other respects. 4%
  - *No indol*, typical in all other respects. 3%
  - *No indol, no clot*, typical in all other respects. 1%
  - *No indol, no clot*, atypical *neutral red*, typical in all other respects. 1%
  - *No indol, no clot*, atypical *glucose, lactose, and neutral red*, typical in all other respects. 1%
  - *Non-motile, no indol, no clot*, atypical *glucose, lactose, and neutral red*, typical in all other respects. 3%
  - *No indol, no clot*, atypical *lactose, and slow liquefiers*, typical in all other respects. 2%
- 63% *completely* positive, *i.e.*, yielding results as follows :—
  1. Motility.
  2. "Gas" in gelatine "shake" culture.
  3. Gas formation in glucose peptone cultures.
  4. ,, ,, ,, lactose ,, ,,
  5. Greenish-yellow fluorescence, neutral red broth cultures.
  6. Indol in broth cultures.
  7. Acid clot in litmus milk cultures.

It will be noted that as regards the seven tests enumerated :—

63 per cent. of the sewage coli were in all respects typical.

37 per cent. failed in one or more respects.

The 37 per cent. comprised 22 per cent. which, although seemingly non-motile, were typical in all other respects ; and with regard to the other 15 atypical microbes :—

4 per cent. were non-motile and non-indol producing.

3 per cent. failed as regards indol.

1 per cent. failed as regards indol and clot.

1 per cent. failed as regards indol, clot, and neutral red.

1 per cent. failed as regards indol, clot, glucose, lactose, and neutral red.

3 per cent. failed as regards ditto, but also non-motile.

2 per cent. failed as regards indol, clot, lactose, and slowly liquefied gelatine.

Hence of the 37 per cent. not *completely* positive, the majority failed to so slight an extent that they could hardly be classed as atypical B. coli. For example, if the test for *motility* be excluded from consideration, no less than 85 per cent. were typical.

The results as regards effluents are shown in the following diagram :—

100 B. coli (effluents).

- 48% *completely* positive, *i.e.*, yielding results as follows :—
  1. Motility.
  2. " Gas " in gelatine " shake " cultures.
  3. Gas formation in glucose peptone cultures.
  4. ,, ,, ,, lactose ,, ,,
  5. Greenish-yellow fluorescence, neutral red broth cultures.
  6. Indol in broth cultures.
  7. Acid clot in litmus milk cultures.
- 52% not *completely* positive.
  - *Non-motile*, typical in all other respects. 13%
  - *No clot*, typical in all other respects. 1%
  - Atypical *neutral red*, typical in all other respects. 3%
  - *No indol*, typical in all other respects. 8%
  - *Non*-motile and *no indol*, typical in all other respects. 2%
  - *No indol, no clot*, atypical *neutral red*, typical in all other respects. 4%
  - *No indol, no clot*, typical in all other respects. 5%
  - *Non motile, no clot*, atypical *neutral red*, typical in all other respects. 2%
  - *No indol*, atypical *neutral red, slow liquefier*, typical in all other respects. 1%
  - Atypical *lactose, no indol*, typical in all other respects. 1%
  - *No indol, no clot*, atypical *lactose*, typical in all other respects. 5%
  - *No indol, no clot*, atypical *lactose* and *neutral red*, typical in all other respects. 2%
  - *No clot*, atypical *neutral red*, typical in all other respects. 1%
  - *Non-motile*, atypical *neutral red*, typical in all other respects. 2%
  - *Non-motile, no indol*, atypical *glucose* and *neutral red*, typical in all other respects. 2%

It will be noted that as regards the seven tests enumerated :—

48 per cent. of the effluent coli were in all respects typical.

52 per cent. failed in one or more respects.

The 52 per cent. comprise 13 per cent. which, although seemingly non-motile, were typical in all other respects :—

1 per cent. failed as regards clotting milk.

3 per cent. failed as regards the neutral red broth test.

8 per cent. failed as regards the indol test.

2 per cent. failed as regards indol and were non-motile.

4 per cent. failed as regards indol, clot, and neutral red.

5 per cent. failed as regards indol and clot.

2 per cent. failed as regards clot and neutral red and were non-motile.

1 per cent. failed as regards indol and neutral red, and slowly liquefied gelatine.

1 per cent. failed as regards the lactose and indol tests.

5 per cent. failed as regards the lactose and indol tests and did not clot milk.

2 per cent. failed as regards the lactose, neutral red, and indol tests and did not clot milk.

1 per cent. failed as regards the neutral red broth test and did not clot milk.

2 per cent. failed as regards the neutral red broth test and were non-motile.

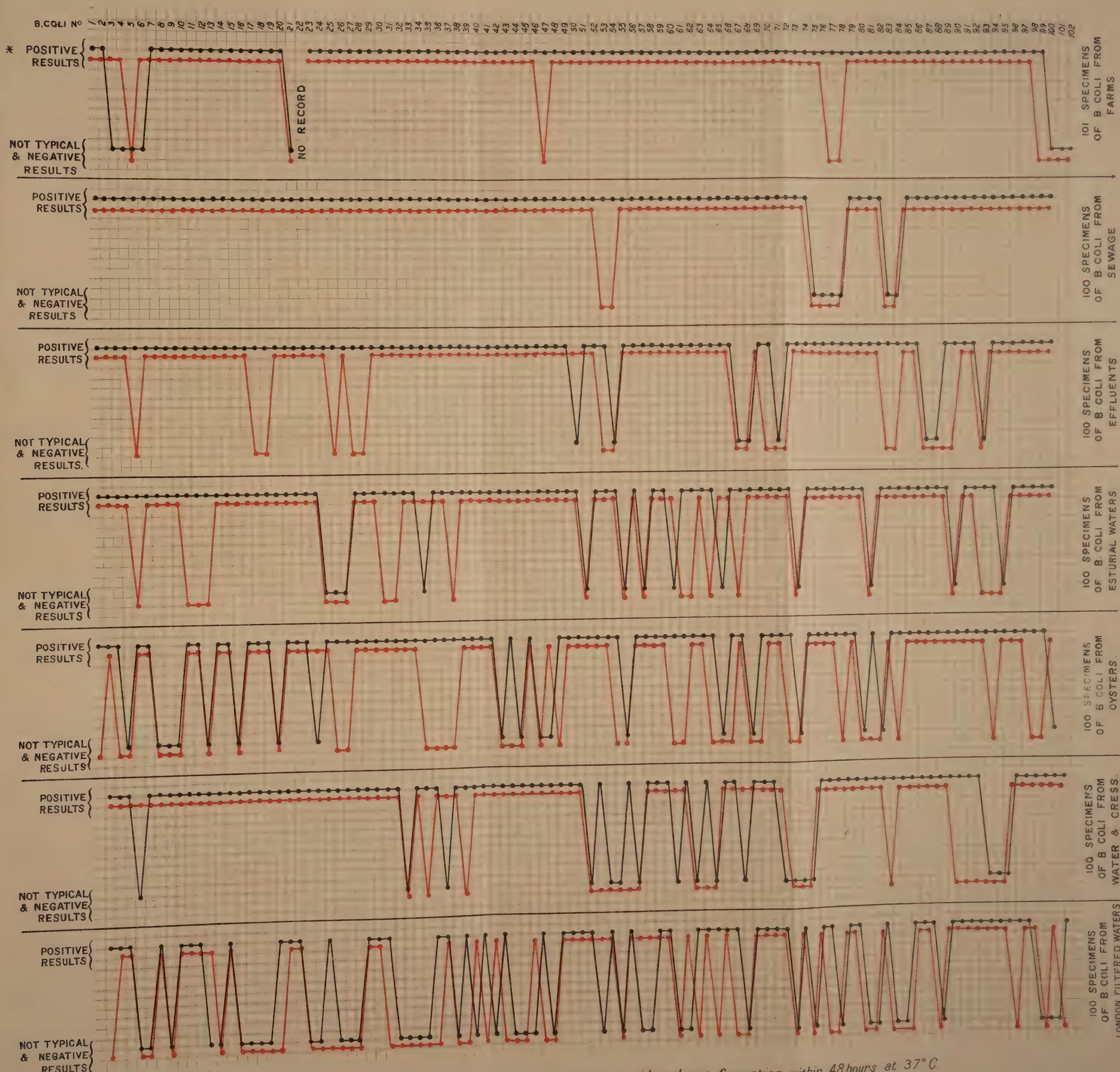
2 per cent. failed as regards the indol, glucose, and neutral red broth tests and were non-motile.

Of the 52 per cent. not *completely* positive, the majority failed to so slight an extent that they could hardly be classed as atypical B. coli. For example, if the test for *motility* be excluded from consideration, 61 per cent. were typical.

Relation between the lactose peptone and litmus milk tests.

The lactose peptone test was seldom used by bacteriologists a few years ago, because it was contended, with a certain amount of reason, that the litmus milk test gave somewhat parallel results. While the value of the lactose peptone test is undoubted, it is well to remember that there

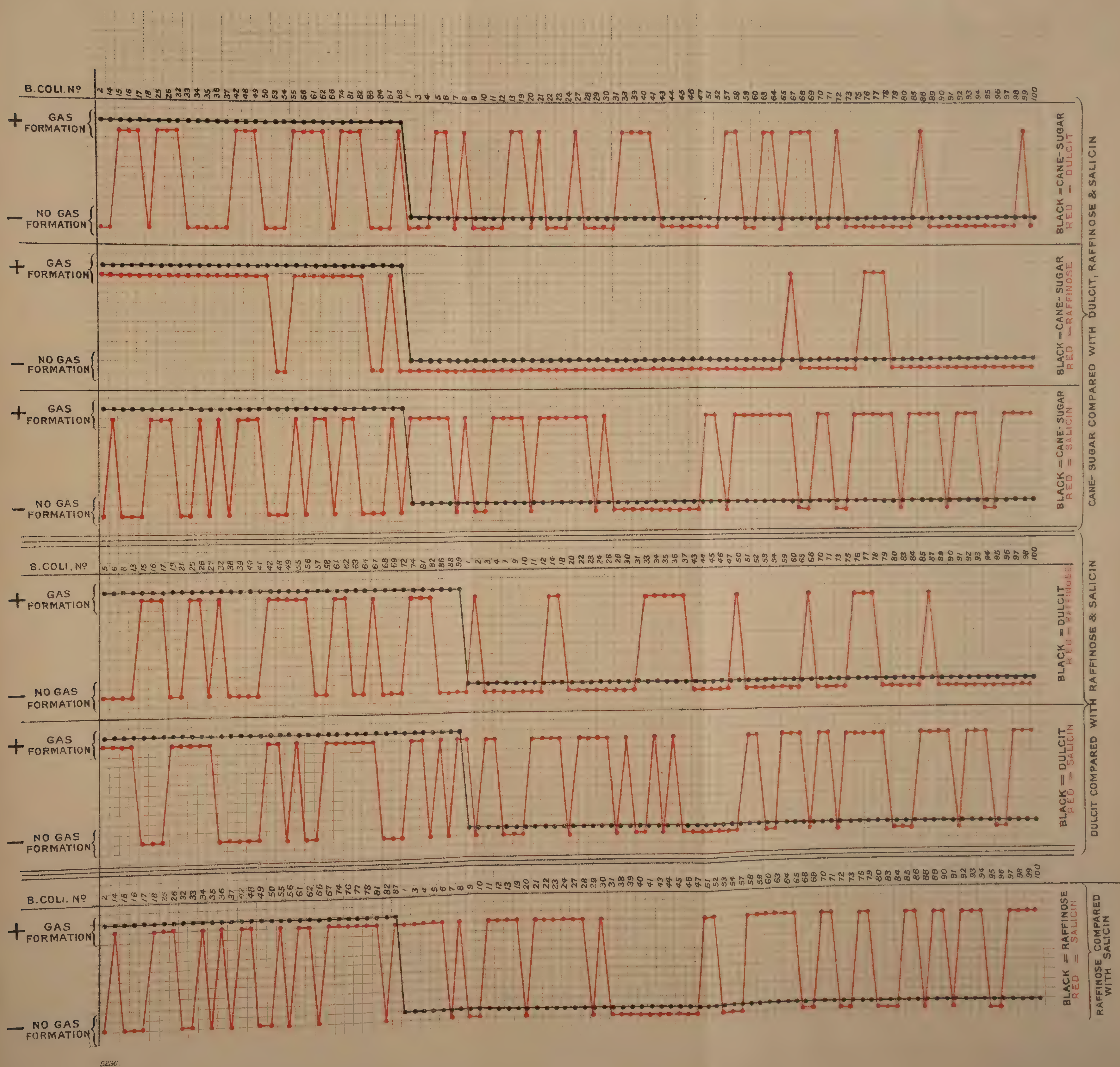
DIAGRAM I. COMPARING THE RESULTS OBTAINED BY THE LACTOSE PEPTONE (•—•—•—•) AND LITMUS MILK (•—•—•—•) TESTS.



* A positive result as regards the lactose peptone test means acid and gas formation within 48 hours at 37° C.

A positive result as regards the litmus milk test means acid clotting of the medium within 5 days at 37° C.

Diagram 2 Showing, as regards the Sewage B. Coli, the Results of the Cane-Sugar, Dulcit, Raffinose & Salicin Tests.



are chromogenic (yellow) microbes bearing no close kinship to B. coli which ferment lactose vigorously. Some of these microbes liquefy gelatine. McConkey was, it is believed, the first to call attention to the occasional presence of these micro-organisms in water. The writer has isolated apparently similar microbes from drinking water, shell-fish, estuarial water, cress, and polluted waters. On the other hand, some highly pathogenic microbes (*e.g.*, Gärtner's bacillus and B. typhosus) do not ferment lactose.

With the object of showing the degree of parallelism between the gaseous fermentation of lactose and acid clotting of milk diagram 1 is given. For comparative purposes the diagram includes the results of the examination of 100 *consecutive* specimens in each case of B. coli isolated from estuarial waters *; oysters †; cress, and water in which cress was being grown ‡; and London filtered water.§ The diagram, of course, bears *no* reference to the *number* of B. coli or coli-like microbes in these different substances. For the sake of simplicity, feebly positive and atypical results are recorded as negative.

It will be noted that the parallelism || between the gaseous fermentation of lactose and acid clotting of milk is striking; that the inability of a microbe to clot milk was more frequent than its failure to ferment lactose; and that the B. coli derived from estuarial waters, oysters, cress, and London waters were much less typical (as judged by these tests) than the B. coli isolated from fæces, sewage, and effluents.

Comparison between the cane-sugar, dulcit, raffinose, and salicin tests.

As the cane-sugar test is not always used, the dulcit test seldom used, and the raffinose and salicin tests practically never employed, it is of interest to compare these tests to see if any relation (direct or inverse) exists between them.

The results as regards the sewage B. coli are shown in diagram 2. In the diagram the cane-sugar results are compared with the dulcit, raffinose, and salicin results; the dulcit results are compared with the raffinose and salicin results; and, lastly, the raffinose are compared with the salicin results. Further, the observations are arranged under two headings, namely, positive (gas formation, varying, however, in degree from "copious" to "traces") and negative (no gas formation) results.

Apparently, there is no constant relation (direct or inverse) between the cane-sugar and dulcit or the cane-sugar and salicin tests, but there is a suggestion of a certain degree of direct parallelism between the cane-sugar and raffinose tests.

The dulcit and raffinose, the dulcit and salicin, and the raffinose and salicin tests do not seem to show any constant correspondence (direct or inverse).¶

* Page 120 *et seq.* } Fourth Report of Royal Commission on Sewage Disposal, Vol. III.
† Page 127 *et seq.* }

‡ Page 3 *et seq.* of Cress Note Book.

|| Page 4 *et seq.* of London Filtered Waters Note Book.

§ Of course, it must be remembered that outside the coli group of bacteria clotting of milk without parallel *gaseous* fermentation of lactose is a common event. For example, many streptococci of excremental origin clot milk, but none, in my experience, produce *gas* in lactose peptone medium.

¶ Possibly the cane-sugar and salicin tests, and perhaps the raffinose and salicin tests, show some slight inverse relation.

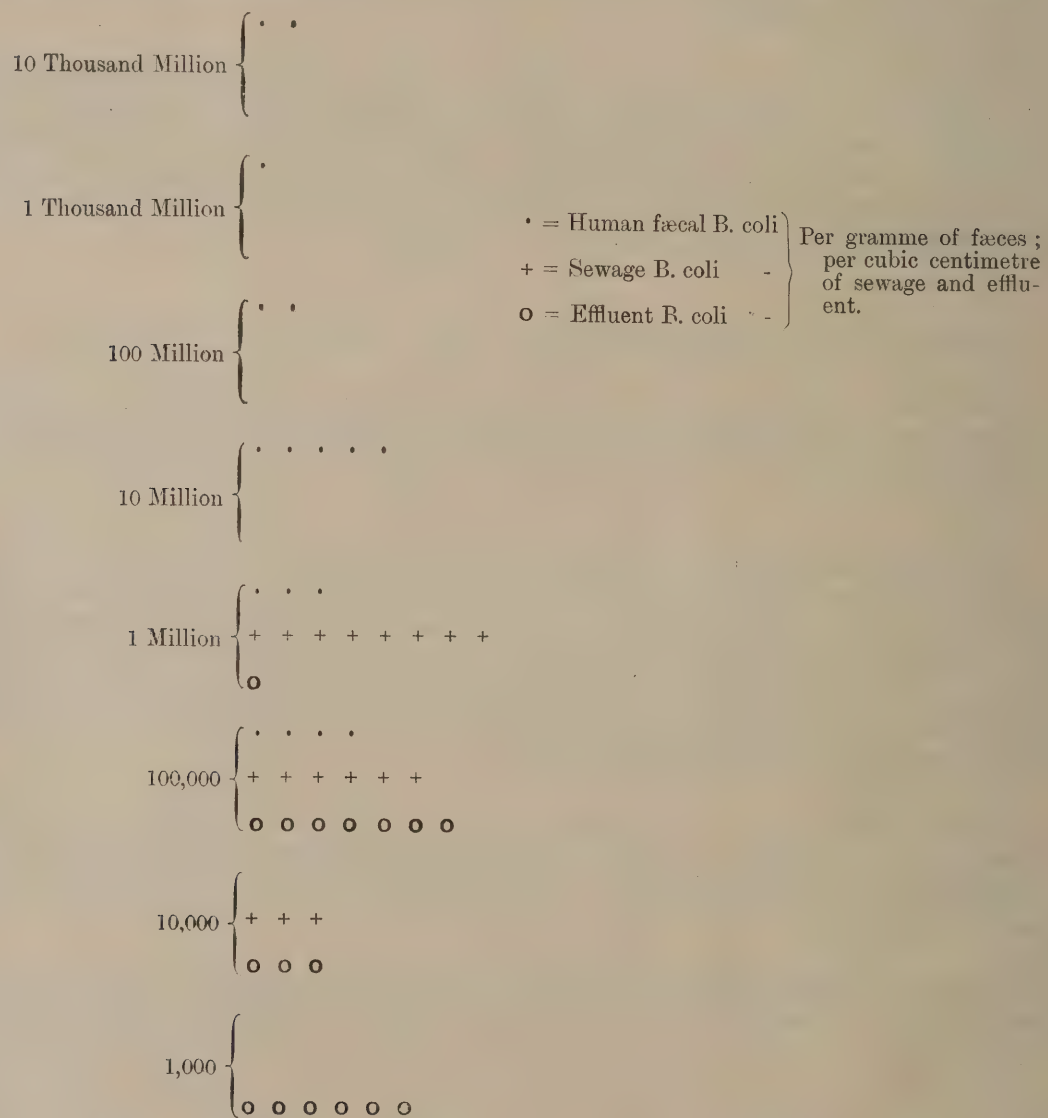
SECTION III.

Comparison between the B. coli of (a) Normal Human Fæces, (b) Sewage, and (c) Effluents.

In instituting this comparison, it needs to be remembered that in sewage containing much trade refuse, and in slop-water sewage, the percentage number of typical B. coli is undoubtedly lower than in purely domestic (water-closet) sewage. Some of the sewages included in this investigation were not purely domestic in character, and some of the effluents were derived from sewage containing trade refuse or a large proportion of slop water.

Numerical abundance.

In the following diagram, the number of B. coli per gramme of fæces in each of the 17 stools submitted to examination and the number of B. coli per cubic centimetre in each of the 17 samples of (a) sewage and (b) effluent are brought into comparison :—



It will be noticed that the number of B. coli was less in the sewage than in the fæces, and much less in the effluents than in the sewage.* Too much stress, however, must not be laid on percentage reduction of B. coli in effluents as compared with sewage. From the bacteriological point of view, and on mathematical lines of reasoning, this may be the only means of gauging the degree of potential danger to health. But the epidemiologist is not misled by figures which indicate a remarkable degree of percentage purification if the *actual* number of objectionable microbes remaining in an effluent is unduly great.

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* For purposes of comparison, one gramme by weight of fæces and one cubic centimetre by measure of sewage or effluent are considered identical.

Percentage number of B. coli giving with each separate test the results stated below.

It is desirable to bring into one table for comparative purposes the results which have been already set forth in separate tables, thus:—

Tests. For the sake of simplicity *feebly* positive and *atypical* results are recorded as negative.*]	Percentage number of B. coli giving with each separate test the results stated in Column 1.		
	Fæces.	Sewage.	Effluents.
Cols. 1	2	3	4
	Per cent.	Per cent.	Per cent.
Motility	89	71	79
Gas in gelatine "shake" cultures	100	100	100
Gas formation in glucose peptone cultures	100	96	98
Gas formation in lactose peptone cultures	92	94	92
Gas formation in cane-sugar peptone cultures	8	29	32
Gas formation in dulcit peptone cultures	55	34	44
Gas formation in mannite peptone cultures	No record	96	100
Gas formation in raffinose peptone cultures	ditto	5	15
Gas formation in salicin peptone cultures	ditto	33	22
Gas formation in inulin peptone cultures	ditto	None	None
Greenish-yellow fluorescence in neutral red broth cultures	98	95	83
Indol in broth cultures	98	85	70
Acid clot in litmus milk cultures	92	92	80
Acid, gas, and clot in lactose peptone milk cultures	90	No record	No record
Reduction of nitrates to nitrites	100	ditto	ditto
Cherry red colour Proskauer and Capaldi medium No. I.	98	ditto	ditto
No definite acidity Proskauer and Capaldi medium No. II.	100	ditto	ditto
28-46 per cent. $\frac{N}{10}$ Na_2Co_3, litmus whey cultures	96	ditto	ditto
Virulence in broth cultures	9	ditto	ditto
No liquefaction of gelatine	100	98	99
Decolorisation by Gram's method of staining†	No record	No record	No record

* It is obvious, however, that the percentage figures will vary greatly according to whether the feebly positive and atypical results are classed as positive or negative. As full details are given in the various tables, the reader may place his own interpretation on the results.

† This test was not used. It appears in this connection to be little better than a fetich. (*See* Section IV.

As regards the comparative data, the points which seem to specially call for note are as follows :—

A smaller percentage of the B. coli derived from sewage and from effluents were observed to be motile and a larger number fermented cane-sugar than was the case with the fæcal B. coli.

The B. coli from effluent were less typical than the fæcal B. coli as regards the neutral red broth, indol, and litmus milk tests.

Generally speaking the B. coli from effluent were less typical than the B. coli from sewage, and the sewage B. coli were on the whole less typical than the fæcal B. coli.

But the results perhaps hardly suggest that even the effluent B. coli *qua* attributes are *much* "safer" than the fæcal B. coli, unless indeed the assumption be entertained that the observed difference in the results is due less to a certain proportion of coli-like microbes (but not true B. coli) being included in the analyses of the effluents than to a general "loss of attribute" amongst the intestinal bacteria in the effluents ; loss of attribute being regarded as a result of separation of B. coli from the animal body and of the treatment of the sewage by one or another process.*

Comparison between the "flaginac" B. coli in fæces, sewages, and effluents.

The great majority of fæcal B. coli yield positive results as regards the glucose, mannite, lactose, neutral red, indol, litmus milk, and Proskauer and Capaldi No. I. tests. The great majority, likewise, reduce nitrates to nitrites, give rise to no definite acidity in Proskauer and Capaldi No. II. medium, and are motile. A minority ferment cane-sugar † and only a few are virulent to rodents under the conditions of experiment. About one-half ferment dulcit.

From the practical point of view, however, there is a great convenience in considering B. coli as a microbe which produces fluorescence (fl) in neutral red broth cultures, acid and gas (ag) in lactose peptone cultures, indol (in) in broth cultures, and acid and clot (ac) in litmus milk cultures. Such a microbe may conveniently be called "flaginac B. coli," ‡ and when this term is applied it means that all the foregoing tests have been employed and have yielded positive results.

Comparing the B. coli in fæces, sewage, and effluents in the above sense, it is to be noted that 85 per cent. both of the fæcal and sewage B. coli were flaginac B. coli ; whereas only 61 per cent. of the effluent B. coli fall under this category.

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* It is desirable to make this point quite clear. The effluents contained a smaller percentage of completely typical B. coli than the sewage or fæces. This fact may be due to several causes acting separately or in conjunction. It may be that the process of sewage treatment leads either to a multiplication of the atypical coli-like microbes at the expense of the typical B. coli or induces typical B. coli to part with some original attributes, or allows both these processes to take place. From the epidemiological point of view the point is of great importance, because "loss of attribute" as regards B. coli would suggest the possibility of "loss of virulence" in respect of pathogenic microbes. It should be remembered, however, that some sewages without corresponding effluents and some effluents without corresponding sewages were examined, so that in this sense the results are not strictly comparable.

† B. coli *communis* does not ferment cane-sugar. It is therefore correct to apply this term to a typical B. coli which does not ferment cane-sugar. But to call microbes which ferment cane-sugar B. coli *communis* seems anomalous. In human fæces about 8 per cent. of the B. coli yield completely positive results, and about 22 per cent. give feebly positive results with this sugar. In sewage the proportion of positive results is higher. The term *communis* is perhaps best dispensed with.

‡ Practically, a "flaginac B. coli" is to be thought of as a microbe which also ferments glucose and mannite ; produces strong acid in litmus whey cultures (about 28 to 46 per cent. $\frac{N}{10}$ Na_2CO_3 required to neutralise) ; gives a positive result in Proskauer and Capaldi No. I. medium and no definite acidity in Proskauer and Capaldi No. II. medium ; and reduces nitrates to nitrites. Its claims to be considered typical are also enhanced if it does *not* ferment cane sugar and if it is found to be motile.

The atypical coli-like microbes may be grouped as follows :—

Coli-like microbes.	Fæces.	Sewage.	Effluents.
	Per cent.	Per cent.	Per cent
Flinac	3		
Flin	5		
Flagin	4		1
Flagac	2	7	10
Flag		1	5
Flac			1
Fl		2	5
Aginac	2		5
Agin			3
Agac			3
Ag		1	4
O *		4	2

It may be of interest to give for comparison some figures, as follows :—

In the oyster inquiry it was found that out of 464 B. coli isolated from oysters (of varying degrees of purity) about 43 per cent. were "flaginac" B. coli.

As regards estuarial waters, out of 183 B. coli, about 66 per cent. were "flaginac" B. coli.

175 B. coli isolated either from watercress or the "washings" of cress, or the water in which the cress was grown, yielded 53 per cent. of "flaginac" B. coli.

Taking 100 consecutive specimens of B. coli isolated in 1903 from the London filtered waters, only 25 per cent. were "flaginac" B. coli.

Considered apart from numerical abundance, however, the foregoing figures may be to some extent misleading. Thus, on the one hand, it is not infrequently found that a high total number of coli-like microbes may be associated with a low percentage of flaginac B. coli; and, on the other hand, that a small total number of coli-like microbes may be associated with a high percentage of flaginac B. coli. But how best to co-ordinate numbers and attributes is a matter yet to be determined.

* This signifies a coli-like microbe which produced gas in gelatine "shake" culture, but gave negative results as regards the foregoing four tests.

SECTION IV.

Tests Recommended for Adoption in the Study of the Biological Attributes of B. coli and Coli-like Microbes.

It is obvious that the more tests applied, the better; it is nevertheless difficult, and in routine work impossible, to apply in each instance every known test.

Much, of course, depends on the nature of the sample and the kind of information that is required. For example, in the case of substances (*e.g.*, sewage, effluents, and grossly polluted waters) known to contain excremental matters in large amount, but few tests need as a rule be applied. But when drinking waters are under examination, and waters concerning which no definite information is available, or waters which although under suspicion have not been proved definitely to be objectionably polluted, the case is widely different.

In what follows it is assumed that the microbe has been isolated in a pure condition; that it has given rise to gas formation in gelatine "shake" culture;* and that it either does not liquefy gelatine at all, or so slowly as not to merit its exclusion from the coli-like group of bacteria.

As regards sewage, sewage effluents, and grossly polluted waters, it is usually sufficient to apply the indol and lactose peptone tests.

In respect of drinking waters, the neutral red broth and litmus milk tests should also be employed, and possibly as well the cane-sugar test and test for motility. Many of the American bacteriologists lay stress on the value of the nitrate broth test, but, although B. coli of human fæcal origin always give a positive result, the atypical coli-like microbes which it is sought to differentiate from typical B. coli commonly also reduce nitrates to nitrites. The mannite test is seemingly too catholic in character (sewage positive 96 per cent.; effluent positive 100 per cent.),† and the dulcit test possibly too selective (fæces positive 55 per cent.; sewage positive 34 per cent.; effluent positive 44 per cent.). The latter test, however, has this advantage, that members of the Gärtner and paracolon groups of microbes commonly yield a positive result. But we are dealing here with tests for typical B. coli rather than tests for differentiating B. coli from the foregoing pathogenic microbes. For a somewhat similar reason Proskauer and Capaldi's media (Nos. I. and II.) are of secondary value as tests for B. coli, although they may be most useful in differentiating B. typhosus from other microbes. The lactose peptone milk test is of use, as practically it combines in one test the information yielded by the lactose peptone and litmus milk tests. The amount of acid produced in litmus whey cultures is no doubt an important factor, but the test need not be employed unless in exceptional cases. A similar remark applies to the test for pathogenicity, and, as so few of the fæcal B. coli were found to be virulent, its use as a routine measure seems hardly justifiable. The inulin test appears to be useless unless it can be shown that atypical coli-like microbes commonly give a positive result with it, and this is certainly not the case in my experience. The raffinose and salicin tests may be of value as

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* Practically speaking, this test yields the same results as the glucose peptone medium. But if the gelatine medium is not properly prepared, or is made with Liebig's extract of meat instead of fresh beefsteak, it is necessary to add glucose, in order to obtain gas formation.

† The same may be said of the glucose test, but there is a great advantage in retaining one comprehensive test, and the glucose test is perhaps the best for this purpose.

a means of separating otherwise indistinguishable B. coli into distinctive groups, but their value as routine tests can hardly be maintained.

MacConkey has found Inulin and Adonite and Voges and Proskauer's test useful for differential purposes, and the American bacteriologists rely a good deal on gas ratios (H and CO_2).

On the whole, the tests for "flaginac" B. coli. namely, the neutral red broth (fl = fluorescence), lactose peptone (ag = acid and gas), indol (in = indol) and litmus milk (ac. = acid and clot) seem most useful for routine work. But there is a good deal to be said in favour of the test for motility and the cane-sugar test. As regards the former, however, it needs to be remembered that 12 per cent. of the fæcal B. coli were not observed to be motile, and many atypical coli-like microbes are highly motile. Thus of 71 gas-forming (but atypical either as regards the indol or litmus milk test or in respect of both tests) coli-like microbes isolated from the Chichester well waters (1900-1) 63 (about 88 per cent.) were motile (App. B, No. 6, Report of the Medical Officer, Local Government Board, 1900-1). Similarly in 1901-2 the figures were: of 45 atypical coli-like microbes 40 were motile (about 88 per cent.). In respect of the cane-sugar test, its use is apt to raise controversial points, as on the one hand Escherich's B. coli communis does not ferment cane-sugar, and on the other hand 8, 29, and 32 per cent. respectively of the B. coli derived from fæces, sewage, and effluent yielded a completely positive result, and a still larger proportion a feebly positive or (?) negative result. Moreover, not only Escherich's B. coli communis but also many of the atypical coli-like microbes met with in actual practice fail to ferment cane-sugar. Perhaps the proposition can be put most clearly by saying that a flaginac B. coli should be accepted as an excremental microbe, and that if it is motile and does not ferment cane-sugar its significance as an indicator of objectionable pollution is thereby increased.*

With a view of showing the behaviour of gas-forming non-flaginac coli-like microbes when subjected to some of the tests which have just been considered an additional piece of work was undertaken. Fifty *consecutive* specimens of gas-forming but non-flaginac coli-like microbes were examined as regards motility, and in respect of the following tests:—Mannite, dulcit, cane-sugar, raffinose, salicin, inulin, and nitrate broth tests. Gram's method of staining was also tried. The results are shown in the accompanying table (Table 5).†

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* It is convenient if these tests are used to record the results in brackets after the words "flaginac B. coli." Thus if a microbe is motile the letter M. and if non-motile the letters N.M. may be used. As regards the cane-sugar test, c.s. + or c.s. – might stand respectively for positive or negative results. A completely typical B. coli in the foregoing sense would be described thus:—Flaginac B. coli (M.; C. S. —). It is assumed that the microbe does not liquefy gelatine, but there are coli-like microbes which do liquefy gelatine slowly. In such a case the letters S.L. (slow liquefier) might be used.

† The non-flaginac coli-like microbes were, as a matter of fact, derived from cress, the "washings" of cress, and the water in which cress was growing. The reader must not infer from this circumstance that either cress or the water in which cress is grown, *need* necessarily be impure bacteriologically. It so happened that I had in my possession fifty non-flaginac coli-like microbes *freshly* isolated from cress and circumfluent water, and it was convenient to utilise these microbes for the purpose in view.

TABLE 5.

BIOLOGICAL CHARACTERS OF 50 GAS-FORMING BUT NON-FLAGINAC COLI-LIKE MICROBES ISOLATED FROM WATERCRESS, "WASHINGS" OF CRESS, AND WATER IN WHICH CRESS WAS GROWING.

Number.	Reference (Cress Note Book). P.	Reference (Cress Note Book). No.	Biological *status* on "flaginac" basis of classification. (The letters in brackets signify a *weak* reaction.)	Motility.	Nitrate broth test :— + = reduction of nitrates to nitrites (2 days at 37° C.)	1 % solution of peptone tinted with litmus solution, together with 0·5 % of :— Mannite. 48 hrs. at 37° C. A = acid. G = gas.	Cane Sugar. 48 hrs. at 37° C. A = acid. G = gas.	Salicin. 48 hrs. at 37° C. A = acid. G = gas.	Raffinose. 48 hrs. at 37° C. A = acid. G = gas.	Inulin. 48 hrs. at 37° C. A = acid. G = gas.	Dulcit. 48 hrs. at 37° C. A = acid. G = gas.	Grams method of staining. D = decolorised.
1	3	46	Flinac - -	+	+	A. G.	A. m. G.	A. sl. G.	A. m G.	Negative	A. m. G.	D.
2	4	1	Aginac. Y.L. -	+	+	A. G.	A. sl. G.	A. sl. G.	A. m. G.	Negative	A. m. G.	D.
3	7	9	Flagac - -	? –	+	A. G.	A. sl. G.	A. sl. G.	A. sl. G.	Negative	Negative	D.
4	9	15	Aginac. S.L. -	+	+	A. G.	A. G.	Negative	A. m. G.	Negative	Negative	D.
5	9	17	Fl(ag) - -	+	+	A. G.	A. G.	A. m. G.	A. m. G.	Negative	Negative	D.
6	9	19	Flag - - -	+	+	A. G.	A. G.	Negative	A. m. G.	Bl. no G.	Negative	D.
7	10	57	Flin(ac) - -	+	+	A. G.	A. sl. G.	A. m. G.	A. no G.	Negative	A. G.	D.
8	14	65	Fl(ac). S.L. -	+	+	A. G.	A. G.	A. G.	A. G.	Negative	Negative	D.
9	14	66	Flag(ac). S.L. -	+	+	A. G.	A. G.	A. G.	A. G.	Negative	Negative	D.
10	14	68	Fl(ag)(ac). S.L.	+	+	A. G.	A. G.	A. G.	A. G.	Negative	Negative	D.
11	14	69	Flag(ac). S.L. -	+	+	A. G.	A. G.	A. G.	A. G.	Negative	Negative	D.
12	14	70	Fl(ac) - -	+	+	A. G.	A. G.	A. G.	A. G.	Negative	Negative	D.
13	17	73	Inac - - -	+	+	A. G.	Negative	A. m. G.	Negative	Negative	Negative	D.
14	17	75	Fl(ac) - -	+	+	A. G.	Negative	A. m. G.	Negative	Negative	Negative	D.
15	17	76	Flag(ac) - -	+	+	A. G.	Negative	A. sl. G.	Negative	Negative	Negative	D.
16	18	98	(Fl)(ac) - -	+	+	A. G.	A. m. G.	Negative	A. sl. G.	Negative	Negative	D.
17	18	99	Flagac - -	+	+	A. G.	A. m. G.	Negative	A. sl. G.	Negative	Negative	D.
18	18	101	(Fl)(ag)(ac). S.L.	+	+	A. G.	A. G.	Negative	A. G.	Negative	Negative	D.
19	20	77	O. Y.L. - -	? –	+	A. G.	Negative	A. G.	Negative	Negative	A. G.	D.
20	22	26	Fl(ag) - -	? –	+	A. G.	Negative	A. G.	Negative	Negative	Negative	D.
21	25	32	Flag(ac) - -	+	+	A. G.	Negative	Negative	Negative	Negative	A. sl. G.	D.
22	26	85	(Fl)ag(ac). Y.L.	+	+	A. G.	Negative	A. m. G.	A. G.	Negative	A. G.	D.
23	26	86	Flag(ac). Y.L. -	+	+	A. G.	Negative	A. m. G.	A. G.	Negative	A. G.	D.
24	26	87	Flag. Y.L. -	+	+	A. G.	Negative	A. m. G.	A. G.	Negative	A. G.	D.
25	26	88	Fl(ag) - - -	+	+	A. G.	A. m. G.	Negative	A. sl. G.	Bl. no G.	Negative	D.
26	26	89	Fl - - -	+	+	A. G.	A. m. G.	Negative	A. sl. G.	Negative	A. G.	D.
27	26	90	Fl(ag) - - -	+	+	A. G.	A. m. G.	A. sl. G.	A. sl. G.	Bl. no G.	Negative	D.
28	27	107	Flagac - -	+	+	A. G.	Negative	A. G.	Negative	Negative	A. G.	D.
29	27	110	Flagac - -	+	+	A. G.	A. sl. G.	Negative	A. no G.	Negative	A. G.	D.
30	28	40	Aginac - -	+	+	A. G.	Negative	A. m. G.	Negative	Negative	Negative	D.
31	29	93	(Fl)agac - -	? –	+	A. G.	A. G.	Negative	A. no G.	Negative	A. G.	D.
32	29	94	(Fl)inac - -	+	+	A. G.	Negative	A. tr. G.	Negative	Negative	Negative	D.
33	32	115	Fl - - -	+	+	A. G.	A. G.	Negative	A. G.	Negative	Negative	D.
34	32	116	Fl - - -	? –	+	A. G.	Negative	Negative	Negative	Negative	A. G.	D.
35	32	118	(Ag)ac - -	+	+	A. G.	A. G.	A. G.	A. G.	Negative	Negative	D.

TABLE 5—*continued.*

BIOLOGICAL CHARACTERS OF 50 GAS-FORMING BUT NON-FLAGINAC COLI-LIKE MICROBES ISOLATED FROM WATERCRESS, "WASHINGS" OF CRESS, AND WATER IN WHICH CRESS WAS GROWING.

Number.	Reference (Cress Note Book).		Biological *status* on "flaginac" basis of classification. (The letters in brackets signify a *weak* reaction.)	Motility.	Nitrate broth test:— + = reduction of nitrates to nitrites (2 days at 37° C.)	1 % solution of peptone tinted with litmus solution, together with 0·5 % of:—						Grams method of staining. D = decolorised.
						Mannite. 48 hrs. at 37° C. A. = acid. G. = gas	Cane Sugar. 48 hrs. at 37° C. A. = acid. G. = gas.	Salicin. 48 hrs. at 37° C. A. = acid. G. = gas.	Raffinose. 48 hrs. at 37° C. A. = acid. G. = gas.	Inulin. 48 hrs. at 37° C. A. = acid. G. = gas.	Dulcit. 48 hrs. at 37° C. A. = acid. G. = gas.	
	P.	No.										
36	32	119	Fl(ag) - -	? –	+	A. G.	A. G.	Negative	A. sl. G.	Negative	Negative	D.
37	32	120	Fl(ag) - -	? –	+	A. G.	A. G.	A. G.	A. G.	Negative	Negative	D.
38	33	122	Flag - - -	+	+	A. G.	A. G.	Negative	A. m. G.	Bl. no G.	A. sl. G.	D.
39	33	123	(Fl)ag. S.L. -	+	+	A. G.	Negative	A. G.	Negative	Negative	A. G.	D.
40	33	124	Flagac - -	+	+	A. G.	Negative	Negative	Negative	Bl. no G.	Negative	D.
41	33	125	Agac - - -	? –	+	A. no G.	A. no G.	A. no G.	A. no G.	Negative	Negative	D.
42	34	126	(Ag)inac - -	+	+	A. tr. G.	Negative	A. no G.	A. no G.	Negative	Negative	D.
43	34	127	Flag. S.L. -	+	+	A. G.	A. G.	A. G.	A. G.	Negative	A. sl. G.	D.
44	34	128	Fl(ag)ac - -	+	+	A. G.	A. m. G.	Negative	A. sl. G.	Bl. no G.	Negative	D.
45	34	129	Flagac - -	+	+	A. G.	A. G.	A. G.	A. G.	Bl. no G.	A. G.	D.
46	34	130	O - - -	? –	+	A. sl. G.	A. no G.	A. no G.	A. no G.	Negative	A. no G.	D.
47	37	131	(Ag)inac - -	? –	+	A. G.	Negative	A. sl. G.	Negative	Negative	A. G.	D.
48	37	133	Flag(in) - -	+	+	A. G.	A. G.	A. G.	A. G.	Bl. no G.	Negative	D.
49	37	134	Flag - - -	+	+	A. G.	A. G.	A. G.	A. G.	Bl. no G.	Negative	D.
50	37	135	Flag - - -	+	+	A. G.	A. G.	Negative	A. sl. G.	Bl. no G.	Negative	D.

Y.L. = chromogenic microbe (yellow) which liquefies gelatine. S.L. = slow liquefier (gelatine). A. = acid. G. = gas. A. m. G. = acid and medium gas formation. A. sl. G. = acid and slight gas formation. A. tr. G. = acid and traces of gas. Bl. = bleached appearance. D. = decolorised. O = a coli-like microbe which produced gas in gelatine "shake" culture, but gave negative results with the other four tests.

With regard to the foregoing coli-like microbes the following points are worthy of note :—

Motility.—80 per cent. of the microbes were motile, so that it appears that coli-like microbes are about as often motile as typical B. coli derived from fæces, sewage, and sewage effluents. Hence it seems the test is of no great value except as a means of corroborating the results of other and more selective tests. Nevertheless the test serves to differentiate into two groups (motile and non-motile) specimens of B. coli which, according to other tests, may seem indistinguishable

Nitrate broth test.—As all the microbes reduced nitrates to nitrites, the practical utility of this test for differential purposes is not very apparent.* From the comparative point of view it may be of interest to note that 200 streptococci isolated from normal human fæces all gave a negative result with this test.

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* In previous reports some stress has been laid on the importance of recording in detail the results of all the tests applied in the study of coli-like microbes as well as of typical B. coli. The value of such procedure is here shown. For if coli-like microbes equally with typical B. coli reduce nitrates to nitrites there is good reason for abandoning the nitrate broth test for differential purposes.

Mannite test.—As 94 per cent. of the microbes yielded completely positive results it is evident that this test is too comprehensive in character to be of much value in differentiating typical B. coli from atypical coli-like microbes.*

Cane-sugar test.—The results may be classified as follows :—40 per cent. completely positive results ; 14 per cent. nearly completely positive results (medium gas formation) ; 8 per cent. produced acid and slight gas ; 4 per cent. produced acid but no gas ; 34 per cent. gave completely negative results. On the whole it may be said that about 54 per cent. yielded positive results and about 38 per cent. negative results as regards gas formation ; the remaining 8 per cent. being doubtful. The results as regards fæces, sewage, and effluent were as follows :—

Fæces.	Sewage.	Effluent.
8 per cent. strongly positive.	29 per cent. positive result.	32 per cent. positive result.
22 per cent. feebly positive.	3 per cent. slight gas formation.	5 per cent. slight gas formation.
36 per cent. (?) negative.	68 per cent. negative result.	62 per cent. negative result
35 per cent. negative.		1 per cent. no record.

Although a much larger proportion of the non-flaginac B. coli fermented cane-sugar than was found to be the case as regards the B. coli of fæces, sewage, and effluent, it is doubtful whether it is justifiable to discard as indicators of objectionable pollution *all* coli-like microbes which do ferment cane-sugar. The better course, perhaps, is to regard a flaginac B. coli which does not ferment cane-sugar as more significant of potentially dangerous contamination than a flaginac B. coli which yields a positive result with this test. Thirty out of one hundred of the fæcal B. coli gave rise to gas formation in cane-sugar peptone medium (8 per cent. completely positive results ; 2 per cent. delayed gas production ; 20 per cent. slight gas formation). Of these 30 B. coli 28 were flaginac B. coli.

Salicin test.—The results may be classified as follows:—30 per cent. completely positive results; 16 per cent. nearly completely positive results (medium gas production); 12 per cent. produced acid and slight gas; 2 per cent. produced acid and a trace of gas; 6 per cent. produced acid but no gas ; 34 per cent. gave completely negative results. On the whole it may be said that about 46 per cent. yielded positive results and about 40 per cent. negative results as regards gas formation ; the remaining 14 per cent. being doubtful. While a higher percentage yielded positive results than was found in the case of the sewage and effluent B. coli, it must be remembered that the effluent B. coli were less typical than the sewage B. coli, and more often yielded positive results with this test Probably the test is chiefly of value as a means of differentiating into separate groups B. coli microbes which without this test might be considered identical.

Raffinose test.—The results may be classified as follows :—32 per cent. completely positive results ; 12 per cent. nearly completely positive results (medium gas formation) ; 18 per cent. produced acid and slight gas ; 12 per cent. produced acid but no gas ; 26 per cent. gave completely negative results. On the whole it may be said that about 44 per cent. yielded positive results and about 38 per cent. negative results as regards gas formation ; the remaining 18 being doubtful. Undoubtedly the proportion yielding positive results was greater than was found in the case of the sewage and effluent B. coli. It might be said, perhaps, that the active fermentation of raffinose by a coli-like microbe detracts somewhat from its claims to be classed as typical B. coli, were it not for the fact that some

* The same is true of the glucose test, and the "gas" in gelatine shake culture test. But while it is desirable to retain, at least, one comprehensive test, it is not advantageous to amplify tests of this kind.

completely typical B. coli do ferment raffinose. The test, however, does serve to differentiate from each other microbes which otherwise seem indistinguishable.

Inulin test.—The results may be classified as follows :—20 per cent. bleached appearance but no gas formation; 80 per cent. completely negative results. So far as gas formation is concerned all the results were negative. As all the sewage and effluent B. coli likewise yielded negative results, the test appears to have no great value for differential purposes.

Dulcit test.—The results may be classified as follows . 26 per cent. completely positive results ; 4 per cent. nearly completely positive results (medium gas formation) ; 6 per cent. produced acid and slight gas ; 2 per cent. produced acid and no gas ; 62 per cent. gave completely negative results. The proportion yielding negative results is higher than was found to be the case with the fæcal B. coli, but the figures do not differ to any notable extent from the sewage and effluent results. Moreover, a larger proportion of the effluent B. coli yielded positive results than the sewage B. coli, notwithstanding the fact that the effluent B. coli were less typical than the sewage B. coli.

Nevertheless, the test is useful as a means of differentiating from each other microbes which yield to other tests similar results.

Gram's method of staining test.—For the purpose of differentiating typical B. coli from atypical coli-like microbes, this test appears to be little better than a fetich. B. coli is decolorised by this method of staining, but it will be noted that so also were all the 50 non-flaginac coli-like microbes of experiment.

To sum up, it is only necessary to repeat that on the whole the tests for "flaginac" B. coli, namely, the neutral red broth (fl = fluorescence), lactose peptone (ag = acid and gas), indol (in = indol), and litmus milk (ac = acid and clot), seem most useful for routine work. Further, that a flaginac B. coli should be accepted as an excremental microbe, and that, if it is motile and does *not* ferment cane-sugar, its significance as an indicator of objectionable pollution is thereby increased.

As regards the significance of non-flaginac B. coli, no bacteriologist can as yet speak with assurance. But as coli-like microbes of any sort are absent from 100 c.c. to 1000 c.c. of unpolluted waters, and are present in enormous numbers in waters known to be excrementally polluted, it appears safe to regard non-flaginac B. coli, when present in any quantity in a water, as suggestive, at all events, of undesirable fouling. The presence in a water sample of coli-like microbes cannot be ignored if the bacteriologist aims at obtaining uniformly quantitative records as regards the B. coli test. Non-flaginac B. coli are, of course, of special significance when it can be shown by multiple analysis that flaginac B. coli are occasionally, if not uniformly, present also, although, perhaps, in small proportion.

SECTION V.

Methods Recommended for the Isolation of B. coli.

The methods adopted in the present investigation have been described already, and in previous reports the whole subject has been considered in detail.

It is desirable, however, to repeat here very briefly the methods which are most useful for the isolation of B. coli.

Dilution.

The decimal mode of dilution should be adopted ; this method has been so fully described in previous reports that it need not be reconsidered here. It is assumed, then, that the substance to be examined has been diluted 10, 100, 1,000, 10,000, and 100,000 times, so that 1 c.c. of the various dilutions represents respectively $\frac{1}{10}$, $\frac{1}{100}$, $\frac{1}{1000}$, $\frac{1}{10000}$, and $\frac{1}{100000}$ c.c., and 0·1 c.c. of the various dilutions represents $\frac{1}{100}$, $\frac{1}{1000}$, $\frac{1}{10000}$, $\frac{1}{100000}$, $\frac{1}{1000000}$ of a cubic centimetre of the original substance.

It remains to be considered whether the subsequent examination should be conducted by means of primary surface plate cultures or primary liquid cultures followed by secondary surface plate cultivations.

Primary Surface Plate Cultures.

0·1 c.c. of the various dilutions should be spread by means of a sterile glass rod (bent nearly at a right angle) over the surface of a series of plates containing gelatine or agar medium. Sugar agars (lactose, glucose, etc.) tinted with litmus, neutral red, etc., are very useful, and the neutral red lactose bile-salt peptone agar medium of MacConkey has many advantages.

Drigalski and Conradi's medium is also well adapted for the purpose. If a gelatine medium is used, the plates should be incubated for two or more days at 20 degrees C.; if an agar medium is preferred, 24 to 48 hours' incubation at 37 degrees C. is sufficient. The colonies resembling B. coli in the plates are next subcultured in gelatine and a "shake" culture made.* If there is "gas" formation and no early liquefaction of the gelatine, the microbe may be classed as a coli-like microbe and its morphological and biological characters carefully studied. I have already considered in detail the best tests to use for this purpose. The gelatine "shake" culture should be kept, preferably for one month, to establish the absence of ability to liquefy gelatine.

There is a good deal to be said in favour of the primary plate method, because the various microbes are plated out and form colonies in exactly the same ratio, the one to the other, as in the original material; whereas in the case of primary liquid cultures followed by secondary plate cultures, the initial proportion of the different bacteria may be greatly altered owing to the unequal rate of multiplication of the different species of microbes in the primary liquid medium.

Nevertheless, if the B. coli are very few in number in proportion to the total number of bacteria, they may be overlooked when using the primary plate method; whereas in the case of the primary liquid culture method the B. coli group usually grows so much faster than the saprophytic microbes that the former are usually easily isolated from the secondary plate cultures. It is, however, a moot point whether or not some of the atypical coli-like microbes may not grow even faster than typical B. coli in the primary liquid cultures.

Primary Liquid Cultures and Secondary Plate Cultures.

1 c.c. of the several dilutions should be added to each of a series of primary liquid cultures. The best medium to use for the primary cultures is a matter open to dispute. Ordinary broth is excellent, and it may be used subsequently for the indol test and the inoculation of rodents.

Neutral red broth, either with or without the addition of a sugar of one or other kind, is also a most useful medium. Peptone media containing one or another kind of sugar and tinted with litmus may also be employed advantageously. The bile salt glucose peptone medium has the great advantage that a negative result proves the absence of glucose gas-fermenting microbes of any kind.

Whatever may be the composition of the primary medium, the subsequent procedure is practically the same.

A small platinum loopful of the contents of the primary tube is transferred to a test tube containing 10 c.c. of sterile water. The tube is shaken and one or more loopfuls used to inoculate a gelatine or agar plate; and the material spread over the surface with a sterile glass rod bent at a suitable angle. The same kinds of gelatine or agar media may be used for the secondary plates as are employed in the case of the surface plate method. The subsequent procedure is exactly the same as in the case of the primary plate method.

A. C. Houston.

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* Glucose gelatine must be used if the gelatine medium has not been prepared from fresh beefsteak.

NOTES BY MR. COLIN C. FRYE ON THE EXPERIMENTS CARRIED OUT AT OLDBURY BY PROFESSOR PERCY FRANKLAND AND MR. H. SILVESTER UPON THE TREATMENT OF THE OLDBURY SEWAGE.

Acting under the advice of Professor Percy Frankland and Mr. H. Silvester, the chemists employed to report upon the best method of disposing of the Oldbury sewage, which contains a large proportion of spent gas liquor from the works of Messrs. Chance & Hunt, Chemical Manufacturers, the Oldbury Urban District Council have lately applied to the Local Government Board for sanction to borrow the sum of £38,300 for the carrying out of a scheme for the extension and improvement of the Oldbury Sewage Disposal Works.

This scheme involves the treatment of the Oldbury Sewage by means of septic tanks followed by triple contact beds, and, as its cost is unusually large and the proposed rate of filtration very slow (15 gallons per square yard per day, on the dry weather flow), it was thought advisable to bring the facts of the case before the Commission.

By the instructions of the Commission, I visited Oldbury on Tuesday, September 25th, 1906, and was conducted to the sewage works by Mr. C. W. Thomlinson, Chairman of the Sewage Committee, Mr. Thomas Shipton, Surveyor to the Council, and Mr. H. Silvester, one of the two chemists mentioned above.

I obtained the following particulars in regard to the history of sewage disposal at Oldbury.

In the year 1880 some 16 acres of very unsuitable land was purchased and laid out for irrigation by the Oldbury Urban District Council, the sum expended being about £16,000, and when the constructional work was completed, this land was irrigated with a precipitation liquor obtained by adding a small quantity of lime to the sewage and allowing the mixture to pass continuously through subsidence tanks.

Of the 16 acres of land, however, only about 7½ acres were available for irrigation, and, in 1881, owing to serious complaints and the unsatisfactory character of the effluent, the Council were driven to seek some means of improvement.

A scheme drawn up by Mr. A. B. Nicholls was accordingly adopted, a loan of £6,000 for this being sanctioned by the Local Government Board in 1892, and the work carried out in 1896 and 1897. The alteration made no difference in the scheme of working, but consisted mainly in the construction of eight new precipitation tanks, together with a large experimental contact bed. A further alteration, which consisted in the construction of more contact beds, was made in 1900.

The general character of the effluent, however, still remained unsatisfactory, and, in 1904, the Staffordshire County Council obtained an injunction against the District Council, on the ground of pollution of the small tributary of the river Tame into which the effluent was discharged.

In the meanwhile (March 1903) the Council called in Mr. Silvester, the analyst for the boroughs of Dudley and West Bromwich and, later (November 1903), Professor Percy Frankland also.

These gentlemen, after carrying out a series of experiments, advised the Council, in a report dated February 28th, 1905, to adopt one of two schemes which they there put forward. Very briefly, these schemes were as follows :—

> *Scheme* 1.—That the spent gas liquor from Messrs. Chance and Hunt's work should be still allowed to enter the sewers, and that the sewage should be first passed through septic tanks and then filtered through *triple* contact beds.
>
> *Scheme* 2.—That Messrs. Chance and Hunt's trade waste should be excluded from the sewers, and that the general domestic sewage of Oldbury should then be treated in septic tanks and upon *double* contact beds.

It was pointed out by Mr. Silvester and Professor Frankland that the main difficulty in the treatment of the Oldbury sewage arose from the admixture with the ordinary waste waters from the population of a large proportion of the trade waste from the works of Messrs. Chance and Hunt, Chemical Manufacturers.

This trade waste is the residual liquor of ammoniacal gas liquor from which Messrs. Chance and Hunt remove the ammonia. Some idea of its character will be gained from the following figures of analysis, which have been kindly supplied to me by Mr. H. Silvester :—

Analyses of Spent Gas Liquor.

Period of time over which analyses were made :—

First Analysis - - - - - May 5th, 1903.
Last Analysis - - - - - May 2nd, 1906.

Results stated in parts per 100,000.

Number of Samples analysed—5.

——	Average.	Max.	Min.	Remarks.
Solids in solution	2,765·2	4,888	2,000	—
Solids in suspension	175·4	*845·2	—	—
Ammoniacal Nitrogen	10·54	14·16	8·0	—
Albuminoid Nitrogen	11·70	17·1	9·4	—
Total Nitrogen other than Ammoniacal Nitrogen (Kjeldahl)	56·75	60·8	52·7	2 samples only.
Oxygen consumed in 4 hours at 80° F.	499·4	564	401·2	—
Oxygen consumed in three minutes	333·9	391·7	300	3 samples only.
Sulphocyanide (CNS.)	153·8	171·7	143·0	4 samples only.
Sulphur as Thiosulphate	46·8	52·5	41·1	2 samples only.
Phenols	140·1	172·3	108	2 samples only.
Combined Chlorine	875·4	1,835	560	—
Alkalinity (expressed as parts of Carbonate of Lime per 100,000)	341·6	400	300	3 samples only.

* The first sample of spent liquor analysed (May 5th, 1903) contained 845·2 parts per 100,000 of suspended matter. In subsequent samples the suspended matter was practically entirely removed by the manufacturers, before discharging the "waste" into the sewers.

On the average this gas liquor is present in the sewage to the extent of one-twelfth to one-fourteenth part of the whole, about 70,000 gallons per day being discharged for three months in the year, and 40,000 gallons per day for the other nine months. The flow of sewage is about 750,000 gallons per day in dry weather.

The following are some particulars of the Oldbury drainage area :—

Population.—27,000 to 28,000.

System of sewerage.—Partially separate.

Storm-water.—Storm-water occasionally arrives at the rate of six times the dry weather flow, but it is exceptional for a rate of six times the dry weather flow to continue for the whole day.

Number of W.C's.—About 3,000 ; the rest of the population is served by the midden system.

Crude Sewage.—The following figures are averages obtained from analyses of six samples. The first analysis of the series was made on May 6th, and the last on June 22nd, 1903. The samples were taken in dry weather over 24 hours, and the various dippings were roughly in proportion to the rate of flow. The sewage of each working day is represented in the results.

Results in parts per 100,000.

——	Average.	Max.	Min.
Solids in suspension	60·72	109·2	40·0
Solids in solution	232·0	305·6	142·0

Average Analysis of Paper filtered Sewage.

——	Average.	Max.	Min.
Ammoniacal Nitrogen	3·19	4·28	2·0
Albuminoid Nitrogen	1·14	1·96	0·445
Oxygen absorbed in 4 hours at 80°F.	38·52	65·4	* 9·6
Combined Chlorine (total silver ppt.)	59·0	76·0	30·6
Sulphocyanide	Sulphocyanide is usually present in the sewage to the extent of 8 or 10 parts per 100,000.		

Although the sewage is thus not strong in nitrogen, it contains, owing to the gas liquor waste a quantity of phenolic substances, sulphocyanides, tar bases, etc., and gives consequently an unusually high figure for "oxygen absorbed," when treated with acid permanganate.

THE EXPERIMENTS.

The experiments made by Professor Frankland and Mr. Silvester, in conjunction with Mr. Shipton, Surveyor to the Council, may be said to have been four in number, as follows :—

(1) The treatment of Oldbury septic tank liquor in small triple contact beds ;

(2) The treatment of Oldbury septic tank liquor in large double contact beds, working at the rate of one filling per day ;

(3) The treatment of Oldbury septic tank liquor in large triple contact beds, for confirmation of Experiment (1) ;

(4) The treatment of Oldbury septic tank liquor upon triple percolating filters.

Experiment I.—The Treatment of Oldbury Septic Tank Liquor in Small Triple Contact Beds.

Area of beds :—

Primary bed	11·5 square yards.
Secondary bed	10·57 ,, ,,
Tertiary bed	10·46 ,, ,,
Total Area	32·53 square yards.

Nature and size of material in all three beds - Clinker graded to pass a $1\frac{1}{8}''$ mesh, but to be retained by a $\frac{1}{8}''$ mesh.

Depth of material in all three beds - 3 feet.

First series of analyses - April 21st 1904 to January 4th 1905.

Beds receiving septic tank liquor at an average rate of 2·44 fillings per 24 hours, with a two-hours contact.

Average rate of treatment over the whole area—about 50 gallons per cube yard per 24 hours.

* Monday's sewage, when the quantity of gas liquor waste in the sewage was small.

Results in parts per 100,000.

Analyses made on *Unfiltered* Sample.

—	Septic tank liquor. Average of 9 analyses.	First contact bed effluent. Average of 4 analyses.	Second contact bed effluent Average of 6 analyses.	Third contact bed effluent. Average of 9 analyses.
Ammoniacal Nitrogen	3·46	2·53	1·88	0·266
Albuminoid Nitrogen	0·75	0·38	0·21	0·097
Oxygen absorbed in 4 hours at 80° F.	27·88	12·14	4·15	1·10
Sulphocyanides	6·21	2·23	0·17	nil.
Combined Chlorine (total silver ppt.)	71·8	92·3	85·9	73·0
Nitrous and Nitric Nitrogen	nil.	nil.	0·66	1·61
Incubator test	—	—	One sample passed, five failed.	All samples passed.

Second Series of Analyses.—December 21st, 1905, to July 12th, 1906.

Beds receiving one filling per 24 hours, with a contact of 3 hours' duration.

Average rate of treatment over the whole area—about 10* gallons per cube yard per 24 hours.

Results in parts per 100,000.

—	Septic tank liquor. Average of 7 analyses.	Third contact bed effluent. Average of 8 analyses.
Ammoniacal Nitrogen	3·14	0·122
Albuminoid Nitrogen	0·849	0·106
Oxygen absorbed in 4 hours at 80° F.	38·0	1·13
Sulphocyanides	10·2	0·11
Combined Chlorine (total silver ppt.)	79·8	69·8
Nitrous and Nitric Nitrogen	nil.	1·86
Incubator test	—	All passed.

The general result of this experiment with the small contact beds, therefore, showed that, working at an average rate of 2·44 fillings per day, two contacts were not sufficient to produce a non-putrescible effluent from the Oldbury septic tank liquor.

With three contacts, however, non-putrescible effluents were obtained when the beds were receiving the septic tank liquor at rates varying from one to three fillings for each bed per day.

Experiment II.—The Treatment of Oldbury Septic Tank Liquor in Large Double Contact Beds, working at the rate of One Filling per Day.

Area and depths of beds :—

Primary bed - 1,174 square yards ; 2′ 9″ deep.
Secondary bed - 243 square yards ; 3′ deep.

Material :

Primary bed - Slag graded between 1¼″ and ⅛″, the bottom six inches of material round the effluent pipes being about 2½″ in diameter.
Secondary bed - Clinker graded between 1″ and ⅛″ diameter.

Duration of Contact - Two hours.

Method of working - One filling for each bed per day.

Rate of filtration - About 30 gallons per cube yard per 24 hours.

Average Analyses of Four Comparative Samples.

Results in parts per 100,000.

—	Septic tank liquor.	Secondary contact bed effluent.
Albuminoid Ammonia	1·02	0·425
Oxygen absorbed in four hours at 80° F.	42·1	13·46
Sulphocyanides	8·73	2·15
Nitric Nitrogen	—	1·09
Incubator test	—	All samples non-putrescible.

Although the above 'effluents' were non-putrescent upon incubation, I understand that this is by no means always the case ; indeed, considering the high "oxygen absorbed" (13·46) and the moderate quantity of nitrate (nitric nitrogen = 1·09) which these particular effluents gave, on the average, it is remarkable that they should have kept upon incubation.

* This was originally 25 ; owing to the gradual loss of capacity in the primary beds, it is of course a slowly diminishing quantity.

EXPERIMENT III.—THE TREATMENT OF OLDBURY SEPTIC TANK LIQUOR UPON LARGE TRIPLE CONTACT BEDS.

Areas and depths of beds :—

Primary bed - - - - - - - - - - - 1,174 square yards ; 2′ 9″ deep.
Secondary and tertiary beds - - - - - - - 243 square yards ; 3′ deep.

Nature and size of material :—

Primary bed - - - - - - - - - - - Slag graded between 1¼″ and ⅛″ diameter, the bottom six inches of material round the effluent pipes being about 2½″ in diameter.
Secondary and tertiary beds - - - - - - - Clinker graded between 1⅛″ and ⅛″ in diameter.

Number of fillings per day to each bed - - - - - - One.

Average rate of treatment per cube yard per 24 hours on the whole area - About 20* gallons.

Results in parts per 100,000.

May 17th, 1905, to July 12th, 1906.

——	Septic tank liquor. Average of 10 samples.	Effluent from tertiary bed. Average of 36 samples.
Ammoniacal Nitrogen - - - - - - -	3·25	0·332 (11 samples).
Albuminoid Nitrogen - - - - - - -	0·890	0·185 (11 samples).
Oxygen absorbed in 4 hours at 80° F. - - - -	37·0	2·74
Sulphocyanides - - - - - - - - -	9·47	0·27
Combined Chlorine (total silver ppt.) - - - -	75·3	61·2
Nitrous and Nitric Nitrogen - - - - -	—	1·56
Incubator test - - - - - - - - -	—	All passed.

Although the effluents from the tertiary bed in this experiment were not quite so good, chemically, as the effluents from the tertiary bed in experiment I., it will be seen that they were nevertheless uniformly non-putrescible.

EXPERIMENT IV.—THE TREATMENT OF OLDBURY SEPTIC TANK LIQUOR UPON TRIPLE PERCOLATING FILTERS.

Area and depth of each bed :—

Primary bed - - - - - - - - 27′ diameter ; 6′ deep.
Secondary and tertiary beds - - - - 28′ diameter ; 3′ deep.

Nature and size of material :

Primary bed - - - - - - - - Clinker and slag.
Top 3′ clinker graded between 1⅛″ and ⅛″ diameter.
Bottom 3′ slag graded from 1½″ to 2½″ diameter.
Secondary and tertiary beds - - - - Clinker graded between 1⅛″ and ⅛″ diameter.

Duration of experiment - - - - - - February to December, 1904.

Method of distribution - - - - - - Adams' continuous feed revolving sprinklers.

Method of working - - - - - - - The method of working the filters was as follows :—

1904, February 13th to May 10th - - - - - - - - Work, 2 hours ; rest, 2 hours.
May 10th to June 23rd - - - - - - - - Work, 1¼ hours ; rest, 2¾ hours.
June 23rd to August 23rd - - - - - - - Work, 1 hour 25 minutes ; rest, 2 hours 35 minutes.
August 23rd to November 12th - - - - - - Work, 45 minutes ; rest, 3 hours 15 minutes.

Average rate of treatment :—

On primary bed - - - - - - - - About 107 gallons per cube yard per 24 hours.
On secondary bed - - - - - - - - About 200 gallons per cube yard per 24 hours.
On tertiary bed - - - - - - - - About 200 gallons per cube yard per 24 hours.
On all three beds, taken together - - - - About 53 gallons per cube yard per 24 hours.

Analyses.—Results in parts per 100,000

April 21st, 1904, to November 2nd, 1904.

——	Septic tank liquor. Average of 7 analyses.	Primary filter effluent. Average of 3 analyses.	Secondary filter effluent. Average of 4 analyses.	Tertiary filter effluent. Average of 7 analyses.
Ammoniacal Nitrogen - - - - -	3·36	3·54	1·9	1·45
Albuminoid Nitrogen - - - - -	0·78	0·72	0·40	0·25
Oxygen absorbed in 4 hours at 80° F. -	26·39	15·29	6·00	3·33
Sulphocyanides - - - - - - -	5·83	3·55	1·8	0·84
Combined Chlorine (total silver ppt.) -	72·3	95·2	85·0	70·4
Nitrous and Nitric Nitrogen - - -	—	—	1·72	2·27
Incubator test - - - - - - -	—	—	{ 2 bad. 2 doubtful. }	All non-putrescible.

* This was originally 27 ; owing to the gradual loss of capacity in the primary bed, it is a slowly diminishing quantity.

If the results obtained in the four experiments briefly described are carefully studied, it will, I think, be agreed that the following main points have been brought out :—

(1) That the Oldbury sewage containing Messrs. Chance and Hunt's waste liquor may be purified by means of biological filters ;

(2) That both contact beds and percolating filters are capable of oxidising the Oldbury septic tank liquor ;

(3) That, working at approximately the same rate per cube yard per day, triple contact filtration gives a better result than triple percolating filtration ;

(4) That, even at so slow a rate of working as one filling a day, *triple* contact filtration is necessary to convert the Oldbury septic tank liquor into a uniformly non-putrescible effluent.

If the figures of analysis for the effluent from the tertiary percolating filters be compared with those of the tertiary contact bed effluent (Experiments I. and IV.), it will be seen that, except as regards oxidised nitrogen, the percolating filter effluent is distinctly the inferior of the two. As it also contains more sulphocyanides than the contact bed effluent, the result may perhaps be looked upon as furnishing further evidence in favour of the theory, first put forward, I believe, by Dr. G. J. Fowler of Manchester, that—by reason of the much longer time of contact with the filtering material—contact bed filtration is preferable to percolating filtration, where chemical substances which have the power of inhibiting the development of bacterial life (*e.g.*, phenols, as in this case) are present in the sewage to be treated.

These experiments have an important bearing on the recommendations contained in the Commission's third Report. They show that it is practicable to purify sewage containing large quantities of gas liquor, but that special arrangements are required. Some witnesses have stated that the treatment of such sewage was impracticable.

COLIN C. FRYE.

October 20th, 1906.

EXPERIMENTS ON THE EFFECT OF DIFFERENT PRECIPITANTS UPON SEPTIC TANK LIQUOR (TAKEN AS REPRESENTING SEWAGE LIQUORS), AS REGARDS THE SUBSEQUENT RATE OF ABSORPTION OF ATMOSPHERIC OXYGEN,

BY DR. G. McGOWAN AND MR. A. F. GIRVAN, B.Sc.

Series I.

Experiment began, December 17th, 1908.

Precipitants used :—Lime and Magnesia.

A sample of Dorking septic tank liquor, No. 109, S, which had been drawn on December 11th, 1908, and allowed to stand until December 17th in a bottle only partly full, was diluted with 39 volumes of tap water, and the mixture was poured into a number of stoppered bottles (eleven bottles in duplicate), these being filled completely. To all, excepting Nos. 1 and 2, small quantities of lime or magnesia had previously been added, as specified in Table I below, and one set of the bottles was kept for five days in an incubator at 18·5° C. In each bottle of the other set the oxygen in solution was determined at the start by the method of Winkler, as modified by Rideal and Stewart, while in the eleven bottles incubated it was determined at the end of five days. The difference between the two determinations represented the amount taken up in each case.

The results are given in the following table.

Table I.

Number of bottle.	Precipitant added, in parts per 100,000, of septic tank liquor.	Oxygen taken up from solution in 5 days at 18·5° C, expressed in parts per 100,000 by weight.
Number.		
1	None added - - - - - - - -	15·5 } = 16·7
2	None added - - - - - - - -	17·8 }
3	Lime, 5 parts - - - - - - - -	16·7
4	Lime, 8 parts - - - - - - - -	16·1
5	Lime, 10 parts - - - - - - -	16·5
6	Magnesia, 5 parts - - - - - - -	17·8
7	Magnesia, 8 parts - - - - - - -	16·9
8	Magnesia, 10 parts - - - - - - -	17·7
9	Lime, 2·5 parts, Magnesia, 2·5 parts - - -	16·9
10	Lime, 5 parts, Magnesia, 5 parts - - - -	16·0
11	Lime, 10 parts, Magnesia, 10 parts - - -	16·5

The foregoing values, Nos. 3 to 11, lie between those of the two duplicates of merely diluted liquor, Nos. 1 and 2, and they are all near to the mean value of those two. In No. 11, the aggregate dose of lime and magnesia together was in the proportion of twenty parts per 100,000 of diluted liquor or 14 grains per gallon, but even this relatively large quantity had no effect on the amount of oxygen taken up in five days, under the conditions of the experiment. It would therefore seem unlikely that the smaller doses which are generally used in practical working would influence the rate of absorption of atmospheric oxygen by a septic tank liquor, as regards the earlier (carbon) stage of oxidation of the organic impurity present.

Series II.

Experiment began January 6th, 1909.

Precipitants used :—Lime, Magnesia and Alumino-ferric.

800 c.c. of Dorking septic tank liquor, No. 115, S, (drawn January 4th, 1909) were diluted with 200 c.c. of boiled and cooled distilled water. Ten separate quantities of 100 c.c. of this diluted liquor were then poured into ten half-Winchester bottles (capacity of each about 1,200 c.c.), various amounts of lime, magnesia and alumino-ferric were added, and the volume was made up in each case to 200 c.c. with the distilled water. The bottles were kept for the greater part of the time at a somewhat low temperature.

From January 6th to 18th, 1909, each bottle was opened nearly every day, its contents gently agitated and the smell noted. After the first nine days, testing for nitrite was begun, and quantitative determinations were made later of nitrite and, subsequently, of nitrate. The results of those tests and determinations are given in Table II.

TABLE II.

	Days from start	1	2	5	8	9	12	13	20	21	22	23	24	26	28	33	The figures for Nitrous and Nitric Nitrogen represent parts per 100,000.
1	Septic liquor alone	†S.	S.	S.	F.S.	F.S.	V.F.	—	—	—	—	—	—	—	—	—	Smell.
		—	—	—	—	0	0	0	·02	·02	·02	·04	·02	·05	·13	·50	Nitrous nitrogen ; parts per 100,000.
		—	—	—	—	—	—	—	—	—	—	—	—	—	·07	·35	Nitric nitrogen „ „
2	Septic liquor alone	S.	S.	S.	F.S.	F.S.	—	—	—	—	—	—	—	—	—	—	Smell.
		—	—	—	—	0	0	0	·02	·02	·02	·03	·04	·10	·25	1.0	Nitrous nitrogen „ „
		—	—	—	—	—	—	—	—	—	—	—	—	—	·03	·34	Nitric „ „ „
3	Septic liquor +	S.	S.	S.	F.S.	F.S.	—	—	—	—	—	—	—	—	—	—	Smell.
	5 parts lime per 100,000	—	—	—	—	0	0	0	trace	trace	·02	·03	·04	·06	·15	·9	Nitrous nitrogen „ „
	parts of septic liquor	—	—	—	—	—	—	—	—	—	—	—	—	—	·23	·15	Nitric „ „ „
4	Septic liquor +	S.	S.	S.	F.S.	F.S.	—	—	—	—	—	—	—	—	—	—	Smell.
	10 parts lime per 100,000	—	—	—	—	0	0	0	trace	trace	trace	trace	·02	·04	·13	·13	Nitrous nitrogen „ „
		—	—	—	—	—	—	—	—	—	—	—	—	—	·05	·37	Nitric „ „ „
5	Septic liquor +	S.	S.	S.	V.F.	V.F.	—	—	—	—	—	—	—	—	—	—	Smell.
	5 parts magnesia per 100,000	—	—	—	—	0	0	0	·02	·03	·03	·05	·07	·15	·30	2·0	Nitrous nitrogen „ „
		—	—	—	—	—	—	—	—	—	—	—	—	—	·08	*0	Nitric „ „ „
6	Septic liquor +	S.	S.	S.	V.F.	V.F.	—	—	—	—	—	—	—	—	—	—	Smell.
	10 parts magnesia per 100,000	—	—	—	—	0	0	0	·02	·03	·03	·04	·06	·15	·35	2·5	Nitrous nitrogen „ „
		—	—	—	—	—	—	—	—	—	—	—	—	—	·01	*0	Nitric „ „ „
7	Septic liquor +	S.	S.	S.	F.S.	F.S.	—	—	—	—	—	—	—	—	—	—	Smell.
	2·5 parts lime +	—	—	—	—	0	0	0	·05	·07	·10	·15	·20	·60	2·00	2·5	Nitrous nitrogen „ „
	2·5 parts magnesia per 100,000	—	—	—	—	—	—	—	—	—	—	—	—	—	0	*26	Nitric „ „ „
8	Septic liquor +	S.	S.	S.	F.S.	F.S.	—	—	—	—	—	—	—	—	—	—	Smell.
	5 parts lime +	—	—	—	—	0	0	0	·03	·03	·03	·05	·06	·12	·25	2·5	Nitrous nitrogen „ „
	5 parts magnesia per 100,000	—	—	—	—	—	—	—	—	—	—	—	—	—	0	*0	Nitric „ „ „
9	Septic liquor +	S.	S.	S.	F.S.	F.S.	—	—	—	—	—	—	—	—	—	—	Smell.
	3 parts lime +	—	—	—	—	0	0	0	·02	·02	·03	·03	·06	·08	·20	2·5	Nitrous nitrogen „ „
	10 parts alumino-ferric per 100,000	—	—	—	—	—	—	—	—	—	—	—	—	—	·04	*0	Nitric „ „ „
10	Septic liquor +	S.	S.	S.	F.S.	F.S.	—	—	—	—	—	—	—	—	—	—	Smell.
	5 parts lime +	—	—	—	—	0	0	0	·02	·02	·03	·03	·06	·08	·20	2·5	Nitrous nitrogen „ „
	10 parts alumino-ferric per 100,000	—	—	—	—	—	—	—	—	—	—	—	—	—	—	*0	Nitric „ „ „

Note.—The bottles were left for the first 28 days in a cool room at laboratory temperature, which at the time was rather low, and for the last few days in a warmer room with a fairly high temperature.

* In these cases some nitrite must have been lost on boiling down, too little calcium bicarbonate having been used.
† S. denotes "sewage smell." F.S. denotes "faint sewage smell." V.F. denotes "very faint smell."

In this second series of experiments the oxidation was carried much further than in the first, but hardly beyond the nitrite-production stage in any case. Practically speaking, there was no difference in the extent to which nitrite was formed in the last six bottles, Nos. 5 to 10. It ought to be added that the presence of such large amounts of nitrite in these made the multiplication error of this determination rather high, hence Nos. 5 to 10 may possibly have contained a little nitrate and rather less nitrite than the figures in the table indicate.* Nos. 1 to 4 show some apparent discrepancies, small but appreciable amounts of nitrate being found in them towards the end of the experiment, but with less nitrite than was sufficient to account for (practically) all the nitrogen originally present.

While the results, therefore, are not quite conclusive, the determinations of this second series—so far as they go—show no marked differences as regards the rate at which oxidation went on in the various liquids, up to the end of the nitrite-production stage.

Series III.

Experiment began February 17th, 1909.

Precipitants, etc., used:—Lime, Magnesia, Alumino-Ferric and Zinc Foil.

3,560 c.c. of Dorking septic tank liquor, drawn on February 16th, 1909, were diluted with distilled water to a volume of 4,750 c.c. Eleven separate quantities of 200 c.c. of this diluted liquor were then poured into eleven half Winchester bottles (capacity of each about 1,200 c.c.), and the volume was in each case made up to 400 c.c. by adding "solutions" of lime, etc., together with the requisite quantity of distilled water. The bottles were kept under a table in a warm room, their relative positions being changed nearly every day in the earlier stages of the experiment, the object of this being to ensure the same conditions for all of them. They were at first opened for a little time daily, the liquid gently shaken, and the smell noted. The results of the analysis of the samples at different periods are given in Table III.

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* Nitrite was determined by meta-phenylene diamine; nitrite + nitrate, together, by the copper-zinc couple method.

TABLE III.

	Days from Start:	12	14	16	19	21	23	26	28	29	35	40	59	63	77	83	107	
	Added Substance.																	
1	Nothing added.	†F.S.E.	F.S.	F.W.	none	—	S.E.	—	—	—	—	—	—	—	—	—	—	Smell
		0·0	0·0	0·0	0·0	0·0	0·0	trace	0·04	0·06	0·12	—	—	—	—	—	—	Nitrous nitrogen
		—	—	—	—	—	—	—	—	0·01	0·04	—	—	—	—	—	—	Nitric ,,
		—	—	—	—	—	—	—	—	2·50	2·66	2·10	—	—	—	—	—	Ammoniacal ,,
2	Nothing added.	F.S.E.	none	F.E.	F.E.	—	S.E.	—	—	—	—	—	—	—	—	—	—	Smell
		0·0	0·0	0·0	0·0	0·0	0·0	trace	trace	0·04	0·25	—	—	—	—	—	—	Nitrous nitrogen
		—	—	—	—	—	—	—	—	0·76	0·72	—	—	—	—	—	—	Nitric ,,
		—	—	—	—	—	—	—	—	2·60	0·85	0·05	—	—	—	—	—	Ammoniacal ,,
3	5 parts of lime per 100,000 of septic liquor.	F.S.E.	F.E.	none	F.E.	—	F.E.	—	—	—	—	—	—	—	—	—	—	Smell
		0·0	trace	trace	trace	trace	trace	0·02	0·05	0·07	0·0	—	—	—	—	—	—	Nitrous nitrogen
		—	—	—	—	—	—	—	—	1·63	2·72	—	—	—	—	—	—	Nitric ,,
		—	—	—	—	—	—	—	—	1·30	0·03	—	—	—	—	—	—	Ammoniacal ,,
4	10 parts of lime per 100,000 of septic liquor.	F.S.E.	F.S.	F.E.	F.E.	—	F.E.	—	—	—	—	—	—	—	—	—	—	Smell
		0·0	0·03	0·06	0·06	0·07	0·09	0·08	0·09	0·09	0·0	—	—	—	—	—	—	Nitrous nitrogen
		—	—	—	—	—	—	—	—	1·91	2·80	—	—	—	—	—	—	Nitric ,,
		—	—	—	—	—	—	—	—	0·80	0·02	—	—	—	—	—	—	Ammoniacal ,,
5	5 parts of magnesia per 100,000 of septic liquor.	F.S.E.	F.S.	F.W.	F.E.	—	F.E.	—	—	—	—	—	—	—	—	—	—	Smell
		0·0	0·02	0·05	0·05	0·06	0·08	0·13	0·15	0·18	0·0	—	—	—	—	—	—	Nitrous nitrogen
		—	—	—	—	—	—	—	1·51	1·72	2·52	—	—	—	—	—	—	Nitric ,,
		—	—	—	—	—	—	—	—	0·80	0·03	—	—	—	—	—	—	Ammoniacal ,,
6	10 parts of magnesia per 100,000 of septic liquor.	F.S.E.	F.E.	F.W.	E.	—	F.E.	—	—	—	—	—	—	—	—	—	—	Smell
		trace	0·05	0·08	0·12	0·15	0·25	0·50	0·52	0·60	0·0	—	—	—	—	—	—	Nitrous nitrogen
		—	—	—	—	—	—	—	1·54	1·80	2·40	—	—	—	—	—	—	Nitric ,,
		—	—	—	—	—	—	—	—	0·55	0·03	—	—	—	—	—	—	Ammoniacal ,,
7	2·5 parts of lime + 2·5 parts of magnesia per 100,000 of septic liquor.	F.S.E.	F.S.	F.E.	F.E.	—	F.E.	—	—	—	—	—	—	—	—	—	—	Smell
		0·0	trace	trace	0·02	0·02	0·05	0·08	0·15	0·27	0·70	—	—	—	—	—	—	Nitrous nitrogen
		—	—	—	—	—	—	—	—	0·13	0·03	—	—	—	—	—	—	Nitric ,,
		—	—	—	—	—	—	—	—	3·00	2·40	0 04	—	—	—	—	—	Ammoniacal ,,
8	5 parts of lime + 5 parts of magnesia per 100,000 of septic liquor.	F.S.E.	none	F.E.	F.E.	—	S.E.	—	—	—	—	—	—	—	—	—	—	Smell
		0·0	0·02	trace	0·04	0·04	0·07	0·07	0·07	0·12	0·0	—	—	—	—	—	—	Nitrous nitrogen
		—	—	—	—	—	—	—	—	1·78	2·68	—	—	—	—	—	—	Nitric ,,
		—	—	—	—	—	—	—	—	0·60	0·03	—	—	—	—	—	—	Ammoniacal ,,
9	5 parts of lime + 10 parts of alumino-ferric per 100,000 parts of septic liquor.	F.S.E.	none	none	none	—	S.E.	—	—	—	—	—	—	—	—	—	—	Smell
		0·0	0·02	0·06	0·06	0·08	0·13	0·07	0·05	0·08	0·0	—	—	—	—	—	—	Nitrous nitrogen
		—	—	—	—	—	—	—	—	1·22	2·40	—	—	—	—	—	—	Nitric ,,
		—	—	—	—	—	—	—	—	1·30	0·03	—	—	—	—	—	—	Ammoniacal ,,
10	About 2 square inches of zinc foil.	F.S.E.	F.E.	F.S.	F.S.	—	F.S.	—	—	—	—	—	—	—	—	—	—	Smell
		0·0	0·00	trace	0·0	0·0	0·0	0·0	0·0	0·0	0·0	—	0·52	1·25	2·40	2·40	0·0	Nitrous nitrogen
		—	—	—	—	—	—	—	—	0·16	0·20	—	0·86	0·55	0·0	0·0	0·0	Nitric ,,
		—	—	—	—	—	—	—	—	2·40	2·40	2·40	1·30	—	0·0	0·0	(2·4)*	Ammoniacal ,,
11	About 4 square inches of zinc foil.	F.S.E.	none	none	F.S.	—	F.S.	—	—	—	—	—	—	—	—	—	—	Smell
		0·0	0·00	0·00	0·0	0·0	0·0	0·0	0·0	0·0	0·0	—	—	—	—	—	—	Nitrous nitrogen
		—	—	—	—	—	—	—	—	0·16	0·20	—	—	—	—	—	—	Nitric ,,
		—	—	—	—	—	—	—	—	2·40	2·50	—	—	—	—	—	—	Ammoniacal ,,

The figures for ammoniacal, nitrous, and nitric nitrogen represent parts per 100,000. * Inferred; not enough sample left to determine this. † E. denotes "earthy smell." S.E. denotes "sweet earthy smell." F.E. denotes "faint earthy smell." F.W. denotes "faint wormy smell." F.S. denotes "faint soapy smell." F.S.E. denotes "faint soapy and earthy smell."

The tabular statement just given shows that in no case was the nitrous stage of oxidation reached in ten days. After twelve days, sample No. 6 (which contained 10 parts magnesia per 100,000, of liquor), showed a trace of nitrite, while in thirty-five days the ammoniacal nitrogen of this sample had been entirely converted into nitrate.

Nos. 3, 4, 5, 8 and 9 gave results very much the same as No. 6.

Nos. 1 and 2 (the two "blanks") did not nitrify so rapidly as the other samples, Nos. 3, 4, 5, 6, 8 and 9, while No. 7 (which contained only 2·5 parts lime + 2·5 parts magnesia), came between the blanks and the others.

It would be desirable to make some further experiments on the same lines, but in the meantime we think that the conclusions to be drawn from the results obtained are :—

1. That the addition of lime and magnesia to septic liquor, in the quantities specified in Table III,—especially the larger amounts, does assist the nitrification of the liquor;

2. That the addition of 10 parts of alumino-ferric with 5 parts of lime, per 100,000, does not retard nitrification;

3. That the addition to septic tank liquor of lime of magnesia or both together, with or without alumino-ferric, in the quantities practicable on a large scale of working, tends to assist nitrification, though not in a very marked degree.

The effect of the addition of metallic zinc in the form of a rather large piece of zinc foil to the septic liquor (bottles Nos. 10 and 11), was remarkable.* No nitrate, and no appreciable nitrite even, was formed in those bottles for 40 or 50 days, by which time all the other samples were completely nitrated. Moreover, when nitrite was eventually produced, it was very slow indeed of passing into nitrate; at the end of 83 days, sample No. 10 was completely "nitrited," there being neither ammonia nor nitrate in the liquid. After 107 days this nitrite had apparently gone completely into nitrate, but unfortunately by this time the sample was exhausted.

We think it would be desirable that this line of investigation should be carried further, in order to gain more information as to what substances facilitate the oxidation of sewage liquors and what substances impede or inhibit this.

Ealing, *August*, 1909.

GEORGE McGOWAN,
A. F. GIRVAN.

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* Mr. A. J. Martin had written to one of us, some time before this, that the nitrification of the Yeovil sewage *appeared* to proceed more rapidly in a small experimental filter, the material of which was contained in a piece of zinc piping, than in another made with earthenware pipe. Zinc foil was therefore used in the above experiment, in order to gain some information on the subject.